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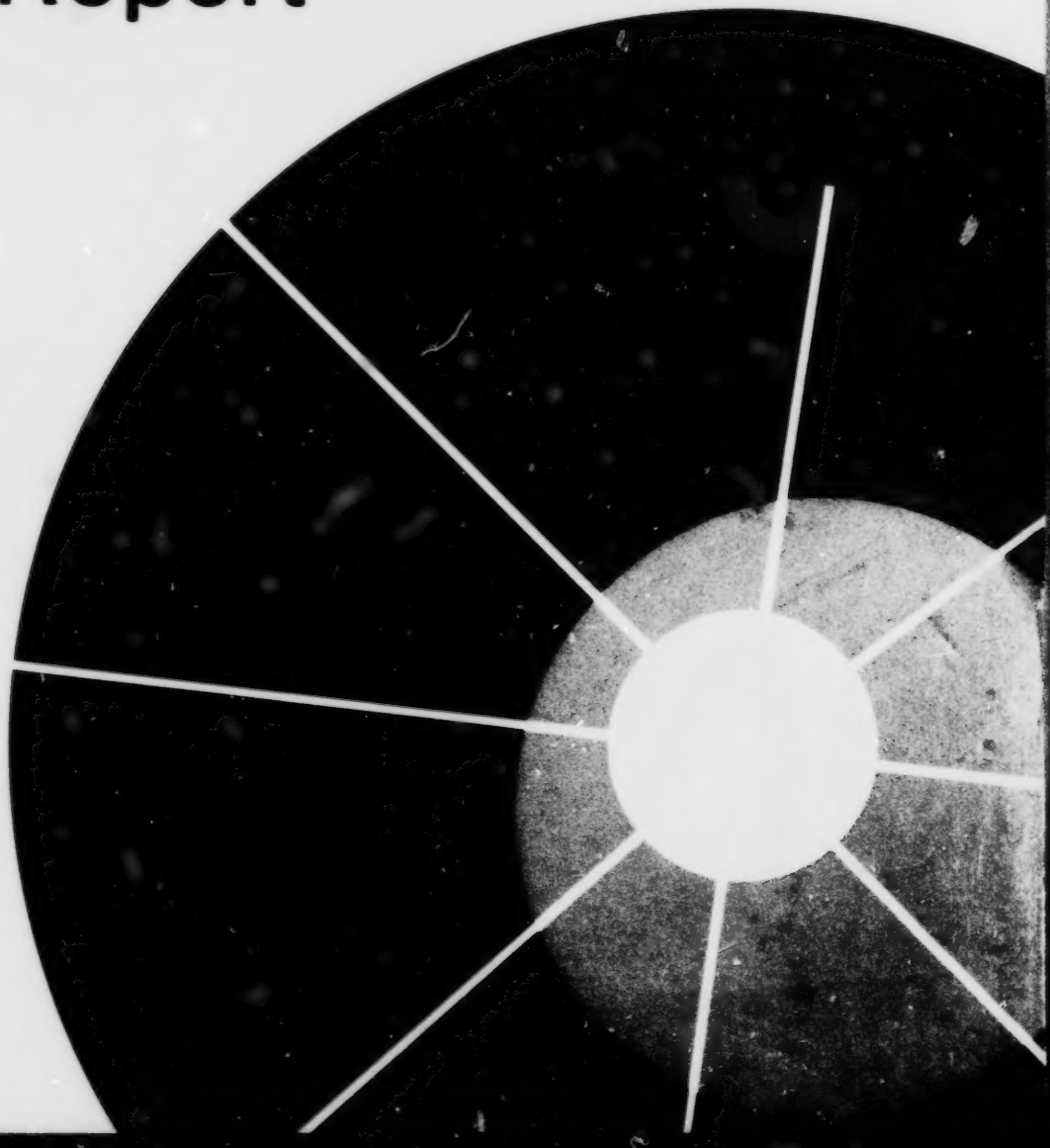
Canada - Saskatchewan Renewables — Conservation Demonstration Program

Final Report



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CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

— To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;

— To create employment in new or existing industries;

— To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Covernment of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

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Hudson Bay Wood Gasifier

Final Technical Report
on a Renewables-Conservation Demonstration Program Project

Conducted By

Saskatchewan Power Corporation

And Supported By

Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada

Project Leader: Dr. D.L. Granatstein

Miscellaneous
Report FP-3

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Report Released: 1981 December

Project Leader: D. L. Granatstein

Project Manager: A. J. Szladow

Director of R & D Centre: M. F. Barabas

EXECUTIVE SUMMARY

The Saskatchewan Power Corporation's wood gasification for power generation program began in 1977 as a possible method of supplying electricity to isolated northern Saskatchewan communities. With this purpose in mind, the 0.25 MW B.C. Research fluidized bed wood gasifier was scaled up into a 1.2 MW Pilot Plant at the Saskatchewan Forest Products plywood mill in Hudson Bay, Saskatchewan, with commissioning of the unit being completed in 1979. A series of experimental runs were completed in 1979-1980, to evaluate the performance of the unit and its potential for commercial application.

Following the installation of a new airlock, grate and ash scraper, as recommended in the previous phase, and a program of preliminary runs, a 60-day period was completed during which the suitability of the Hudson Bay wood gasification system for continuous operation was evaluated. It was concluded that serious deficiencies exist in the available scale-up procedures and expertise. Areas requiring major changes include the feed system, to alleviate the back-leakage of product gases, and to prevent overheating in the combustion zone, the grate/ash removal system, and the mode of operation -- fixed or fluidized bed. Because the gasifier was designed to run in the fluidized mode, and in fact operates as a fixed moving bed, problems have arisen with ash removal and overheating.

Stack gas and waste water effluents were found to pose no serious threat to the environment, and can be safely disposed of without producing pollution

problems. The scrubber, installed for work in this phase, has operated very well, producing a cool, clean gas which burns well in the diesel and in the Maxon burner.

A comparison of wood gasification to diesel oil generation of electricity revealed that, over the next 15 years, wood gas produces cheaper electricity than does diesel, provided that the cost of the wood feed does not exceed $8 (1981 $) per oven dried tonne. In real terms, wood-produced electricity is a viable alternative only when a free source of waste wood is available, such as the situation in which the plant is sited at the source of the waste wood, and is operated by the waste wood producer, who may benefit additionally by a credit to the electricity production cost in the case where a charge was normally levied for waste disposal.

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INTRODUCTION

Background

The decision of the Saskatchewan Power Corporation to enter the field of wood gasification for power generation came after a study had been published (Stobbs and Verma, 1977) on the conversion of wood to electrical energy for use in isolated northern communities. A review of available conversion technologies singled out the gasification of wood followed by combustion of the gas in a modified diesel engine/generator as the most promising approach. Advantages seen for this route included the following: 1) the size range of the plant can be scaled to the size of community it is to serve; 2) operation of the plant does not require the use of skilled labour; 3) by-products are few; and 4) the capital cost of such a plant is attractive.

The Corporation decided to scale up the 0.25 MW B.C. Research (Vancouver) fluidized bed gasification system into a 1.2 MW (4.22 GJ/h) Pilot Plant. The Saskatchewan Forest Products plywood mill in Hudson Bay, Saskatchewan was chosen as the site for installation of the Pilot Plant because of the availability of chipped and hogged wood feed and the possibility of technology transfer to the forest products industry in Saskatchewan.

Scale-up engineering and construction were carried out by Lamb-Cargate Industries Ltd. (New Westminster, B.C.) in 1978, with the commissioning of the unit completed on 1979 03 20. (SPC R & D Report No. 4476-1978-1-Alternate Energy, 1979).

In Phase One of commissioning the plant, preliminary testing was achieved, with the objective of determining whether or not a sufficient

quality wood gas could be produced, and to decide what testing, additions and modifications might be required in the next phase of operations.

In the 1979-1980 phase of the project, the modified diesel engine/generator was installed, with the objective being to obtain detailed engineering and performance data for the gasifier/diesel system. Reliability of various components of the plant was examined, the environmental acceptability of the cleaning train effluent was determined, and the economics of wood gasification for power generation in isolated northern communities and in a sawmill operation were evaluated.

In the course of this phase of operations, combustion characteristics of the product gas from different types of wood feed (particle size, species, moisture content) were studied using a Maxon industrial burner. Various technical difficulties were encountered and a number of design improvements were recommended (Weisgerber, 1980).

Project Objectives and Scope

In the current phase of operations of the Hudson Bay Wood Gasification Pilot Plant (1980-1981), designated as Phase IV, the objective has been to prove commercial viability and acceptability of the Hudson Bay Gasifier (fixed bed mode) by running the plant for an extended period, during which gas produced would either be burned in a Maxon burner to simulate heat production for a wood-drying kiln, or be combusted in the diesel engine/generator for the production of electricity. This objective would be carried out by first implementing the recommendations made in the previous phase of operations.

It must be stressed here that the work statement proposed by the Corporation and reproduced in Appendix E of this report did not include carrying out major design changes. Modifications that were completed in this phase have addressed only those changes which were felt necessary to properly test the feasibility of the plant. The necessity for major design changes has been recognized during the course of the testing, and these are presented as recommendations to be considered with respect to any future demonstration projects.

SYSTEM DESIGN

General Description

Figure 1 presents a schematic diagram of the major plant components. Appendix A contains working drawings of new and/or modified equipment.

Gasifier

The Hudson Bay wood gasification system was designed for an output of 4.22 GJ/h of low heating value (about 5 MJ/m^3) wood gas. The gasifier is 4 m in height, with the lower section having an internal diameter of 1.2 m, and the upper, expanded freeboard section having an internal diameter of 1.8 m. Materials of construction include a carbon steel outer shell, a central, 7.6 cm rock wool insulation layer, and an inner, 10 cm layer of cast alumina refractory.

To facilitate the maintenance of the ash removal system, the windbox has been bolted to the bottom of the gasifier. Combustion air is distributed by means of a pinhole grate supported above the windbox. The grate is sectional and has a cast lining as insulation from the high combustion zone temperatures occurring directly above it. Windbox access is through a cleanout door.

The gasifier is supplied with a 48 cm manhole for access to all interior space above the grate. There are 8 ports to accommodate thermocouples for obtaining the gasifier temperature profile, and 4 ports for pressure sensing via manometers. Two sets of tempered glass capped ports are provided for optical sensing of fuel height.

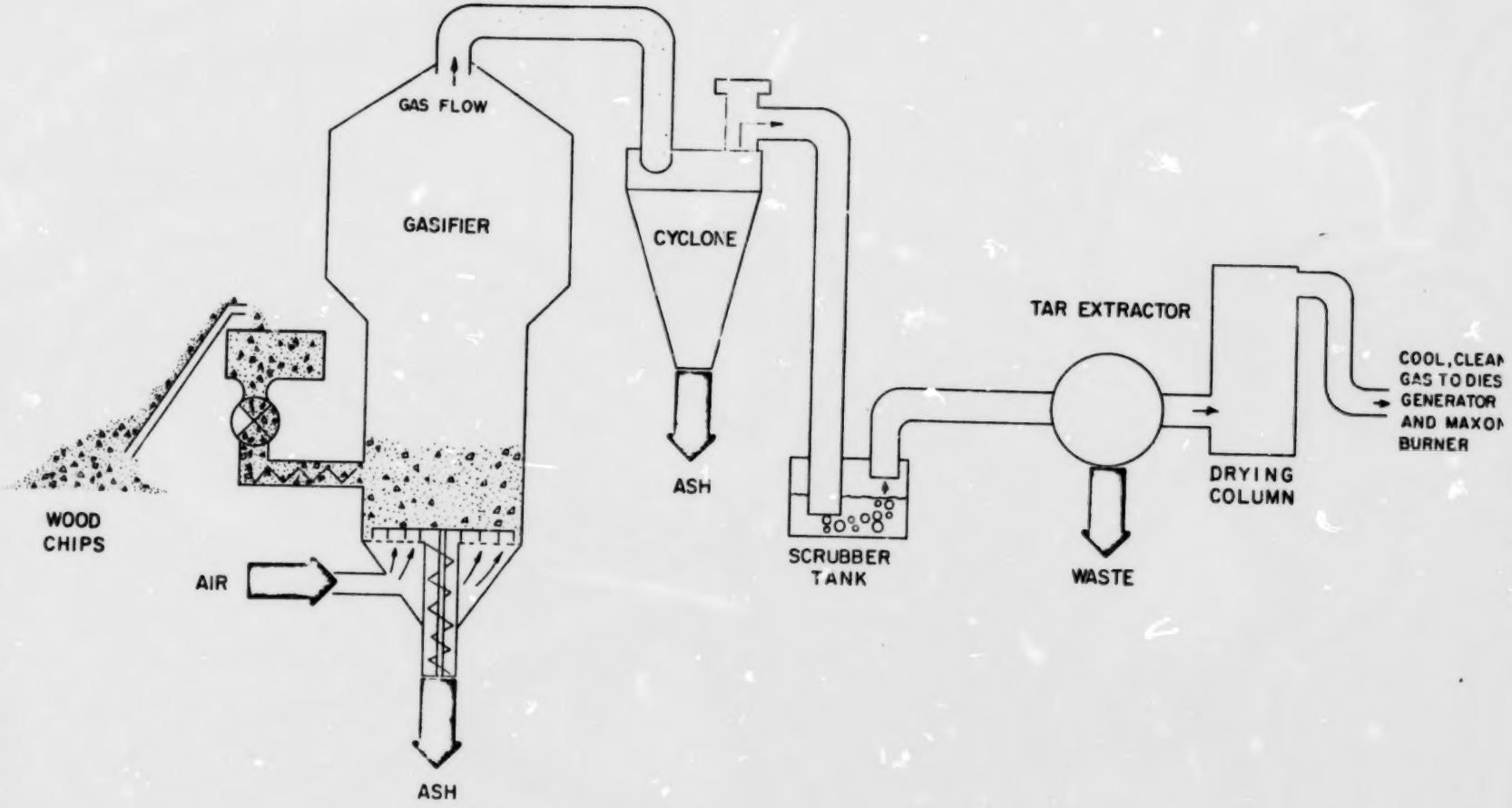

Figure 1.
HUDSON BAY WOOD GASIFICATION PROCESS SCHEMATIC

Feed System

The feed system is composed of a shift bin, drag conveyor, metering bin, rotary air lock, and a screw conveyor.

A live bottom shift bin, having a capacity of 6 m^3, an open top for loading and an access door to facilitate repairs, sits at the bottom of an inclined drag conveyor, which carries the fuel from the shift bin up to the metering bin. The metering bin is also equipped with a live bottom discharge and has been graduated to indicate the volume of full or partial loads, with the full mark being equivalent to a load of 1.28 m^3.

The horizontal drag chain conveyor running through the bottom of the metering bin is driven by a hydraulic motor through a 70:1 gear reducer. An hydraulic power unit, complete with an electrically driven pump, flow regulator valve, pressure relief valve, and solenoid valve control the flow and pressure of hydraulic fluid to the motor. The 12-position flow regulator valve directs fluid to the hydraulic motor, with the excess fluid recirculated through a reservoir.

A 2.25 kW gear motor, and a belt-driven reducer equipped with forward and reverse (to free the system in case of blockage, by reversing direction of revolution) drive the screw conveyor. An "8 inch floating seal airlock", manufactured by Joy Manufacturing Co. (Canada) Ltd. was purchased for this phase of operations to prevent back-leakage of product gas through the feed system. The airlock was supplied with a cast, one-piece rotor, consisting of 8 chisel-edged blades (since ground down and replaced with belting-grade, fibre-reinforced rubber wiper blades) which were to produce a shearing action

as they came into contact with the heavy cast, floating seal, which bore down on the rotor by gravity. The rotor is driven by a 1750 rpm, 0.56 kW motor, and a Boston Flanged Gear Reducer.

The airlock sits under the drag chain beside the metering bin, and on top of the feed screw pipe. Square openings on both the top and bottom of the airlock, with 20 cm sides, provide a maximum feed rate of 6.85 m^3/h (slightly more than 5 metering bin loads per hour) with the rotor turning at 11 rpm.

The feed screw, 15 cm in diameter, is equipped with heavy duty, 6.2 mm thick flighting. It extends from the airlock through the gasifier wall to the inner refractory lining. This extension through the inner lining, a modification in the first phase of operations, was a successful attempt to alleviate a plugging problem which occurred in the feed pipe at the gasifier entrance.

The feed screw pipe was fitted with a compressed air injection port midway along its length, in order to establish a net positive flow of gases into the gasifier, and thus lessen the backflow of gases out through the airlock. This approach was only partially successful, however, and was thought to be the cause of other encountered problems (to be outlined in a later section of the report).

Combustion Air System

The combustion air feed system is comprised of a turbo-pressure blower, heat exchanger and burner.

The turbo-blower has a design delivery rate of 12 m^3/min of air at 70°C and 12 kPa gauge pressure. (At 315°C this drops to 6 kPa gauge pressure.) A manual damper on the blower outlet regulates the air flow. A 12.7 cm diameter pipe carries the air through an orifice plate (for velocity and thus mass flowrate measurements) into the windbox.

The air preheater consists of a double-shell, direct-fired heat exchanger, capable of delivering air at 315°C. Dimensions of the preheater are 1.2 m diameter by 2.3 m long. The preheater is supplied with a 0.45 GJ/h oil burner system equipped with a CdS cell flame detector, an oil pump, and a combustion air blower.

Ash Removal System

An ash rake (rabble arm), screw conveyor and ash box make up the ash removal system.

The ash rake, of solid 310 S.S. construction, is shaft mounted directly above the pinhole grate. It is powered by a 375 W electric motor-reducer system which turns it at 6 rpm, providing a maximum output of 590 N·m of torque. The vanes, welded to the ash rake arm, are at such an angle as to plough the ash toward the centrally mounted ash discharge screw. The discharge screw and ash rake share the same shaft and power supply, which are reversible to correct a possible jamming condition. The screw conveyor transports ash by way of a manual gate-controlled chute to the ash bin below. The ash box, with a capacity of 0.95 m^3, is mounted on wheels and is capable of being uncoupled from the gasifier. Clean-out is accomplished through a side-mounted door.

Gas Flaring System

Product gases are directed through a cyclone (to be discussed with the gas cleaning train, which follows) to the flare system, which consists of two manually operated valves, a flare chamber, flare burner, and stack.

A cross-tee located on the cleaned gas exit of the cyclone is provided with two manually operated valves. The valves are employed to direct gas either to the flare or to the diesel engine/Maxon burner for conversion to useful energy. When the diesel or Maxon burner is operating, excess gas can still be directed to the flare for burning.

The flare chamber is refractory lined and is equipped with a manually adjustable louvre at the bottom to regulate combustion air. A 0.20 MJ/h oil burner with CdS cell flame safety igniter, oil pump, and combustion air blower provide gas ignition. A totally enclosed hood captures all combustion products, directing them to the stack, which is 0.3 m in diameter, and extends 9 m above the hood.

Gas Cleaning Train

The gas cleaning system is made up of the following elements: a cyclone, scrubber, centrifugal tar extractor, tar/water separator, coke block dryer, and suction blower.

The cyclone is a 2 m tall, externally insulated, cone-shaped structure, having a diameter decreasing from 1.2 m at the top (raw gas entrance) to 0.3 m at the bottom (particulate discharge). Hot raw gas enters tangentially near the top, and due to centrifugal force, ash and carbon particles fall to and

are discharged at the bottom, with clean gas leaving at the top. Good insulation prevents condensation of tars on the walls of the cyclone.

The carbon and ash from the cyclone are discharged into the cyclone hopper which is mounted on wheels for easy removal, has a 0.95 m^3 capacity, and which is equipped with a cleanout access door.

Cleaned gases from the cyclone which are not burned in the flare are next directed to the scrubber, composed of a water box of 0.57 m^3 capacity, an inlet and an outlet gas pipe. Water is kept in the water box at such a level (about half-full) that the bottom of the inlet pipe is below the water line, while the outlet pipe entrance is above the water line. In this way the incoming gas is percolated through the water. The gas inlet pipe is also equipped with three water spray nozzles. The total effect of the scrubber is a cooling of the gas, and the removal of any remaining particulate matter, as well as some of the tarry matter.

Effluent from the scrubber (and from the centrifugal tar extractor, to be described below) is pumped (375 W motor) to the tar/water separator, a 0.17 m^3 open drum constructed in such a way that tar is allowed to settle by gravity (to be collected for further processing or burning for process heat) while tar-free water is skimmed off the top for further processing and disposal.

Cleaned gas from the scrubber enters the centrifugal tar extractor through a spray of cold water from a nozzle located in the gas inlet. The extractor consists of a 0.6 m diameter disc which rotates at 2200 rpm in a 0.75 m housing (motor is 3.75 kW). Eight radial vanes are riveted to the disc to direct tar and water to the perimeter space and thence through a 375 W pump

to the tar/water separator. Clean, cool, tar free gas leaves through the central area of the extractor and is routed to the coke block dryer.

The coke block dryer is a cylindrical container of 2.13 m height and 0.61 m diameter, having access doors on the top, and on the side, near the bottom. Gas enters the bottom of the dryer through a perforated swash plate, which supports a load of coked wood blocks. These blocks remove the last traces of tar, as well as any moisture picked up in the scrubber and tar extractor. The blocks should be replaced after about two months of operation, with the used blocks being gasified or burned for process heat.

Clean, cool, dry gas leaves the dryer at the top, having been pulled through the gas cleaning train by a suction blower, the Chicago Blower Industrial SQ Fan. This blower has a capacity of 30 m^3/min at a suction of 35 cm water. The gas is then directed via a two-way valve to either the Maxon burner or the diesel engine for combusting.

Maxon Industrial Burner

The 1.4 MW Maxon Modified Wide-Range Industrial Burner is designed specifically for the combustion of a low heating value gas. The burner, 15 cm wide, (larger than for a burner operating on natural gas) is equipped with a pressure pilot operated on propane, a flame rod, combustion air blower, a microratio valve assembly, and an emergency shut-off valve. The microratio valve assembly is made up of two butterfly valves which adjust air to fuel ratios for various firing rates. Due to the low heating value of the fuel gas, the combustion air and fuel gas are both injected through the burner's larger port -- the air inlet -- allowing design firing rates to be met.

Diesel Engine/Generator

The diesel engine, a Deutz 12 cylinder, air cooled engine, Model KHD FL 12 413 F, is rated at 200 kW for diesel oil operation. A blower partially compresses and injects the low heating value gas into the engine. Modifications made by Imbert Energietechnik GmbH (W. Germany) have included the reduction of diesel fuel consumption to 2.7 L/h which is equivalent to 11 percent of the fuel requirement at the rated load, and conversion of the air intake manifold to a gas/air mixer. The diesel oil is ignited in compression which in turn ignites the gas air mixture. Air/fuel ratio is regulated by two manually operated butterfly valves in the mixer, while flowrate into the engine is controlled by an hydraulic governor.

A Brown Boveri electric generator, rated at 150 kW, 240 V, is frame-mounted with the diesel engine. The electric load is provided by six 25 kW electric forced air resistance heaters.

Control Room

The control panel is made up of start/stop buttons, indicating lights, and temperature, pressure and flow displays. Chromel-alumel (type K) thermocouples which read temperatures of the combustion air, fuel bed at various heights, exit gas and combustion products in the stack, are tied to a multipoint temperature chart recorder housed in the control panel. Ports in the gasifier are connected to manometers to provide pressure drop data across the pinhole grate and the fuel bed. Flow data are obtained via manometers attached to orifice plates, which yield information on the combustion air as well as the product gases.

Control panel functions include activation of the solenoid valve on the hydraulic power unit (which controls the metering bin conveyor), the screw conveyor motor and the rotary airlock motor, all controlled by one start/stop button. Another button operates the oil burner on the combustion air preheater. The ash rake is controlled by a button on the panel; however, the reversible gear to overcome a blocked condition in the ash removal system is located on site. Manual or automatic operation of the pilot oil burner on the flare can be selected at the control panel. Finally, the combustion blower, the suction blower (to pull gas through the gas cleaning train), and the centrifugal tar extractor are all turned off or on at the control panel. All other functions are controlled on site.

The control system includes several safety features. To maintain gasifier temperatures within safe operating limits, the exit gas thermocouple is connected to a temperature controller. When the set temperature is exceeded, the controller activates a pump which wets down the feed in the screw conveyor. Through experience, however, it has been found that this is a poor way to control gasifier temperature. Two methods are used to prevent overpressure in the gasifier. A pressure switch connected to the gasifier outlet shuts down the combustion air blower when the pressure exceeds 120 cm water, and a 20 cm diameter rupture disc will relieve the pressure should it exceed 350 cm water. In addition, various pieces of equipment are interlocked to protect the system.

Gas sampling is also accomplished in the control room. A pump draws a sample from the gasifier outlet through a knockout pot (located on the gasifier) to remove moisture, tar and particulates. The gas sample is next

filtered twice before entering the Fisher gas partitioner. The analyzed sample is exhausted outside the control room, and an integrator is programmed to translate the analysis into gas composition on a volume percent basis.

System Modifications

Major modifications were made to the Hudson Bay gasification system to prepare it for extended operation.

A knife-edged rotary airlock (described earlier) was installed to replace the previous airlock which had deteriorated badly. In the new airlock, the entire rotor is a heavy, one-piece casting. The former airlock had less substantial vanes welded to a central shaft, and these sheared off when tramp iron was introduced accidentally to the system with the wood chips. No problems of this kind were encountered with the new airlock. However, the supplied 0.56 kW motor did not appear to have enough power to cut wood chips jammed between the knife edge and the floating seal, as the shear pin failed repeatedly. The system was modified by grinding back the knife edges and attaching fibre-reinforced, belting grade rubber wiper blades, in order to maintain a relatively gas-tight seal while allowing the blade to give when a wood chip was caught between it and the floating seal.

The suggestion of installing an intermediate hopper before the feed screw, isolated with two knife-edged gate valves was considered as an alternative to the new airlock. It was felt that the small unit considered would suffer the same fate as the rotary airlock. A much larger, more

expensive unit, which would have a greater chance of success, was also considered (but outside the scope of the contract). This larger unit would require physically raising the entire conveyor system, an operation which was deemed to be both very costly and time-consuming, and thus very impractical at this stage of the testing.

Two new rabble arms were fabricated of heavy, solid 310 S.S., a temperature resistant alloy with a high Ni-Cr content. The previous rabble arms were of lighter construction, fabricated of hollow 316 S.S. pipe, and were badly damaged by high temperature. They were internally air cooled, and this served only to increase the rate of deterioration at the air exit ports. Tests were conducted to determine the torque required to rotate the rabble arm under a full load of wood chips (approximately 1.1 m high) and it was found that a 3.75 kW motor would be needed (to replace the existing 375 W motor). This, in itself was not a problem, but gear reduction to drive the rabble arm at 6 rpm was very expensive, and not available as a standard item. It was decided instead to remove the load from the rabble arm by placing a second grate above it to support the wood chips.

Thus two 113 cm diameter grates were cast of H.S. Meehanite iron, a high temperature resisting alloy. These grates were cast in six parts which separately fit through the manhole and could be bolted together inside the gasifier. The grates had integral legs to clear the rabble arm, but this necessitated cutting off the ends of the rabble arm (a few centimetres). The grates were 2.5 cm thick, and consisted of a grid pattern to allow ash to fall through to the rabble arm below, while supporting the wood chips during gasification.

A covered area for dry storage of the wood chips was considered; but the idea was rejected as difficulties would be encountered loading and unloading with the front end loader. Instead, a much simpler solution was adopted. A waterproof tarpaulin was purchased and has successfully kept the wood chip moisture content at about 30-35 percent throughout this phase of operations. As this moisture level was suitable for gasification purposes, construction of a chip dryer was deemed unnecessary.

It was suggested that an insulated line be constructed from the cyclone outlet to the Maxon burner inlet, bypassing the cleaning train in order to conserve sensible heat. Previous to the installation of the scrubber, a test was run to determine the feasibility of this suggestion. Gas was fed to the burner through the centrifugal tar extractor with its water spray shut off. Almost immediately, tar was seen to drip from the burner and it continued to do so throughout the operation. While operation in the proposed mode would be more efficient, it is felt that the cost of maintenance to the burner would more than offset the energy gain. For this reason, the insulated bypass line was not installed.

The cleaning train has been modified due to the need for a cooler, cleaner gas to be combusted in the diesel engine. The scrubber was constructed and installed for this purpose. In addition to cooling the gas to the proper combustion temperature, the scrubber removes much of the tar, and allows a lower water flowrate to be used in the centrifugal tar extractor. Previously the water consumption was judged to be too high.

The use of an air-cooled heat exchanger to cool the cleaning train water was considered (although not included in the work statement) in order that water might be recycled. However, a check with equipment manufacturers revealed that a heat exchanger of the capacity required for our operation would cost about $30,000. It was felt that this cost was not justified by a pilot plant of this size, and this option was not considered further.

Gas was also rerouted through the coke block dryer. Previously it had entered the top and exited through the bottom. It was felt that gravity was working against the drying operation as removed tar and water would eventually settle near the gas exit. The piping was altered so that gas to be dried entered the bottom and left at the top through the drier wood blocks.

Many minor modifications were undertaken to improve performance of the gasifier. The flare hood was reinforced to support the taller stack which had been previously installed. The piping between the gasifier and the cyclone was insulated to prevent the condensation of tar in the cyclone.

Orifice plates were installed in the dirty gas line to the cyclone and in the clean gas line exiting the drying column. In this way, gas production can be measured at all times, and as well, when the diesel or burner is operating, the amount of gas that is being flared can be determined by difference.

A plate was installed over the airlock hopper to force the wood chip feed to fall directly into the airlock. Previously some wood was missing the airlock and being dragged back by the conveyor belt. This caused the hydraulic system to overload, and the conveyor to stop operating.

A tar/water separating drum (previously described) was constructed and put into operation for preliminary treatment of waste water.

A further attempt was made to reduce the product gas leakage through the airlock. A 3.8 cm line was connected between ports on the feed screw housing and the centrifugal tar extractor inlet, in hopes that the suction blower could aid in removal of leaking gas, by routing it through the Maxon burner. A valve at the tar extractor inlet end acted as the control mechanism, and the suction pipe was used only when the compressed air line on the feed screw housing was not operating (to avoid the possibility of an explosive mixture). This method was only partially successful, with about 10 percent of the leaking gases being removed. Calculations indicated that a 12 cm diameter pipe would be required for efficient removal of the leaking gases; however, this was deemed inadvisable for two reasons. First, the risk of an explosive mixture would be greater as air would be sucked in through the airlock (and as well, the line might become clogged with the wood chip feed). Second, it was felt that the combustion zone might be shifted into the feed screw housing, damaging the screw. For these reasons, this method of leakage control was abandoned.

GASIFIER OPERATION

Equipment Performance

Operation of the gasifier in this phase of the work had as its objective the achievement of a 15-day continuous run, consisting of seven 7-hour days during which the diesel engine/generator was to be operated, followed by eight 7-hour days during which either the diesel engine/generator or the Maxon industrial burner was to be operated. This objective was not achieved for the reasons outlined in the following section "A Discussion of Problems Encountered". The contract specified that attempts to achieve a 15-day continuous run were to be made over a test period of 60 days, and this was in fact what occurred.

Failure to achieve a 15-day continuous run was the result of many factors, including inappropriateness of the plant design and mechanical breakdowns.

Three preliminary runs were conducted to determine the readiness of the plant for an attempt to achieve a 15-day continuous run. Once the plant was operating satisfactorily, the 60-day period was begun and 12 runs were achieved. Operating data for these runs are presented in Appendix B.

Throughout the preliminary and formal runs many mechanical breakdowns were evidenced, but none was so severe that it could not be overcome. Problems that could not be overcome included severe gas leakage and gasifier overheating. Although several attempts were made to correct these faults, no progress was made, and it was concluded that a redesign of the equipment was

essential to fully overcome the severe problems encountered. The section entitled "Conclusions and Recommendations" includes suggestions for redesigning the plant.

Air to Fuel Ratio, Moisture Content, Type of Feed

Work performed in a previous phase (Weisgerber, 1980) on these subjects was considered sufficiently complete to require no further testing in this phase; however, for completeness, the salient features of the work are included here, and comparisons with results from the present study are drawn when data are available.

Data were collected during gasifier operation using spruce chips, aspen chips, spruce planer shavings, and aspen hog fuel. Moisture content of the feed varied between 11 and 61 percent by weight. The gasifier firing rate ranged from 234 to 318 kg/h (on a dry basis), and the air to fuel ratio covered the range 2:1 to 3:1 with a maximum air feed rate of 800 kg/h.

Figures 2 and 3 depict the carbon monoxide, hydrogen and carbon dioxide concentration in the product gases versus the air/fuel ratio. The concentration of carbon monoxide and hydrogen decrease as the air/fuel ratio increases. The carbon dioxide concentration, however, increases, since an increase in air flowrate causes the combustion zone to move higher in the gasifier, thus hindering adequate gasification. This study has concluded that the concentration of carbon monoxide is the most reliable candidate for a possible control strategy, due to a high correlation coefficient ($R = 0.61$) for its regression line (Figure 2).

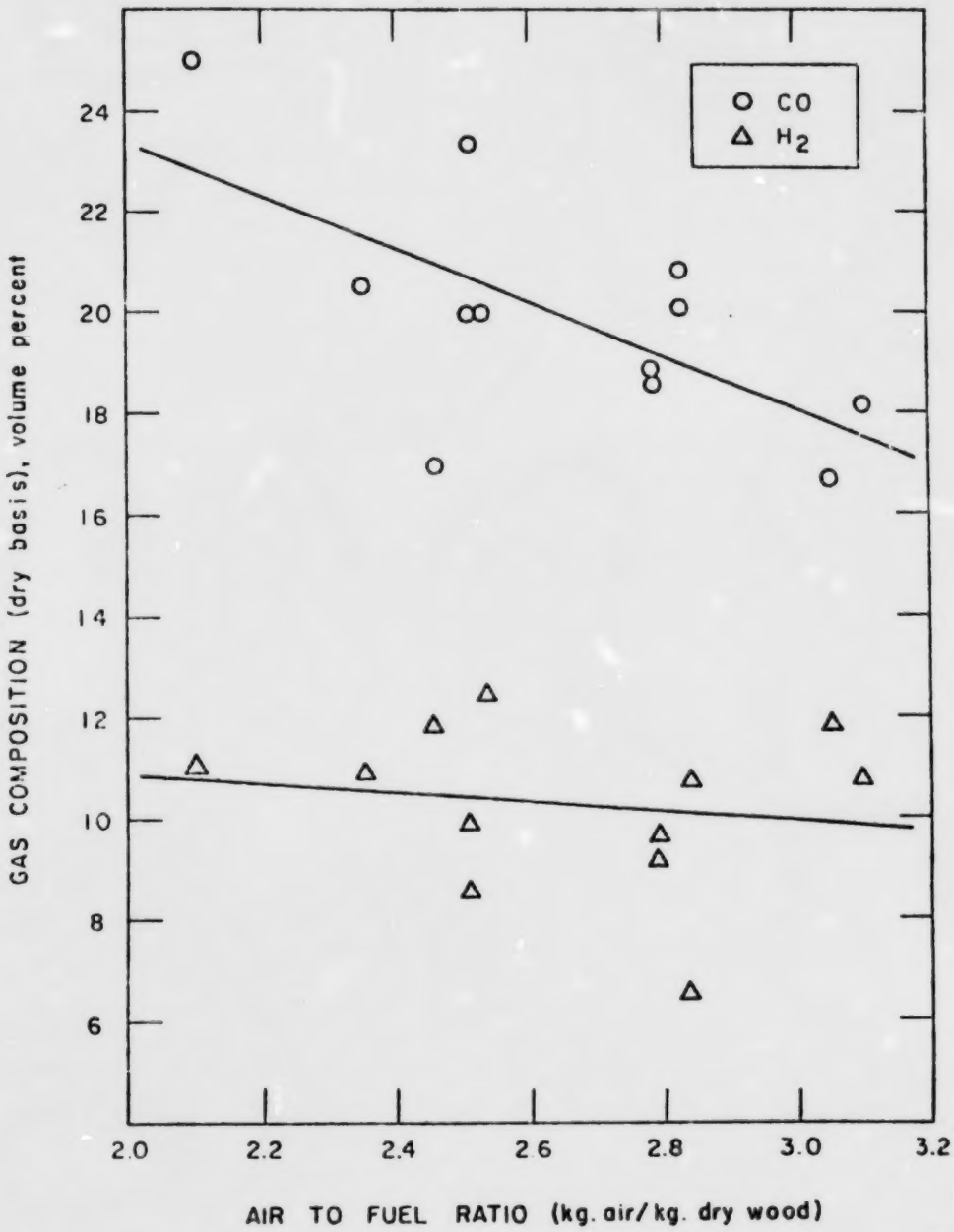

Figure 2. CARBON MONOXIDE AND HYDROGEN CONCENTRATIONS AT VARIOUS AIR TO FUEL RATIOS

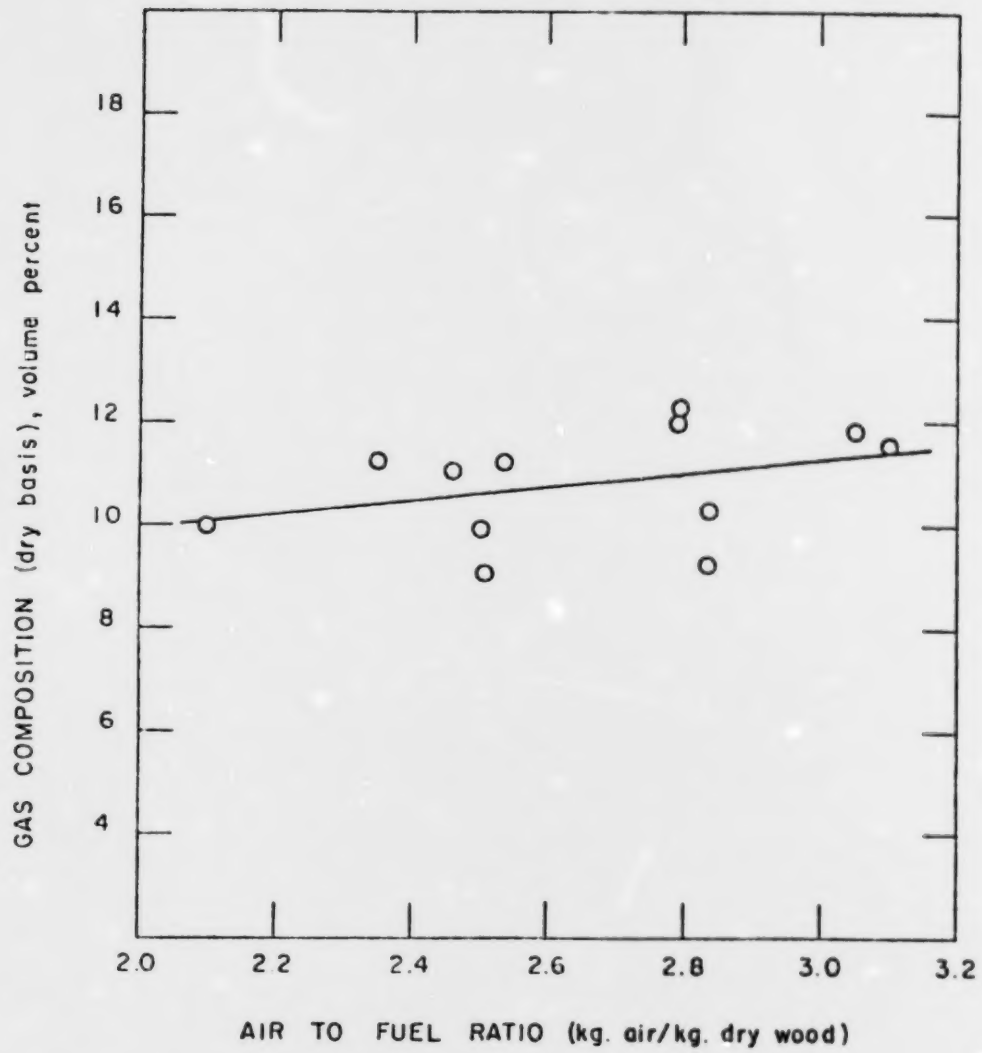

Figure 3. CARBON DIOXIDE CONCENTRATION AT VARIOUS AIR TO FUEL RATIOS

No correlation between air to fuel ratio and gas constituents can be seen in the present work, but the results of Weisgerber are believed to be generally applicable. One point of interest is that the methane concentration in the product gases is the determining factor as to the heating value. Perhaps experimental work should be done to maximize methane production, possibly by the use of a catalyst.

The air/fuel ratio (position of the combustion zone) also controls the gas heating value (Figure 4), thermal efficiency and the gasifier output (Figure 5). As the air/fuel ratio increases, the heating value of the gas decreases, while the gasifier throughput increases to a maximum at a ratio of 2.8:1. The maximum throughput, however, does not correspond to the maximum heating value of the gas, which occurs at a ratio of 2.1:1.

Work done in the present phase of operations employed air to fuel ratios ranging from 0.5 (June 09) to 3.05 (June 16). Most runs were performed at ratios below 2.0. The reasoning behind this was an attempt to control the temperature in the combustion zone, by partially starving the feed of oxygen. As can be judged from the combustion zone temperatures, this tactic was not entirely successful.

Apparent air to fuel ratios are not strictly accurate. In an attempt to control temperatures, the air flow was sometimes shut off for short durations. For runs which lasted for only a few hours, termination of the run might have occurred immediately after feeding a fresh load of wood chips to the gasifier, leaving the feed unconsumed. The effects of these two possibilities tend to cancel one another, making the apparent air to fuel ratios a good

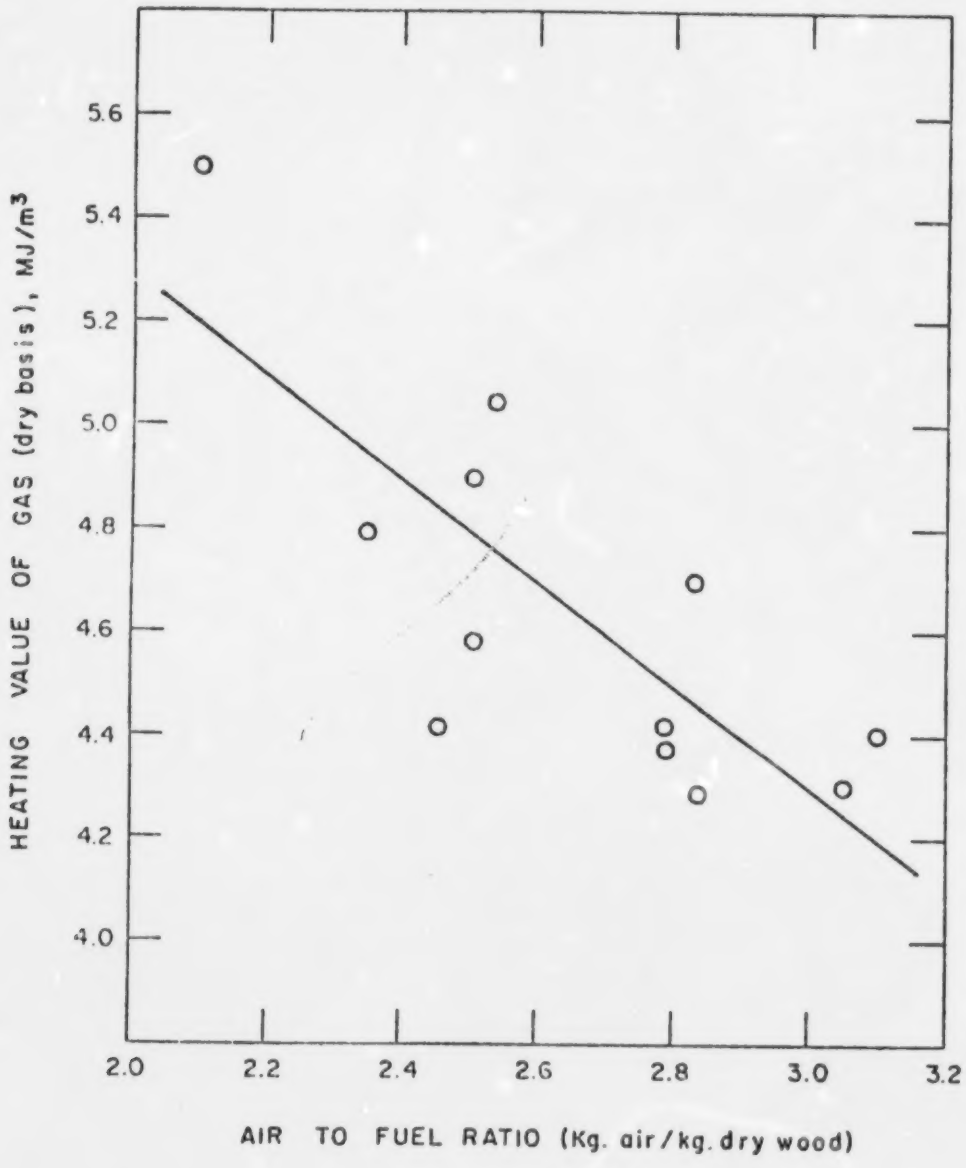

Figure 4. HEATING VALUE OF GAS AT VARIOUS AIR TO FUEL RATIOS

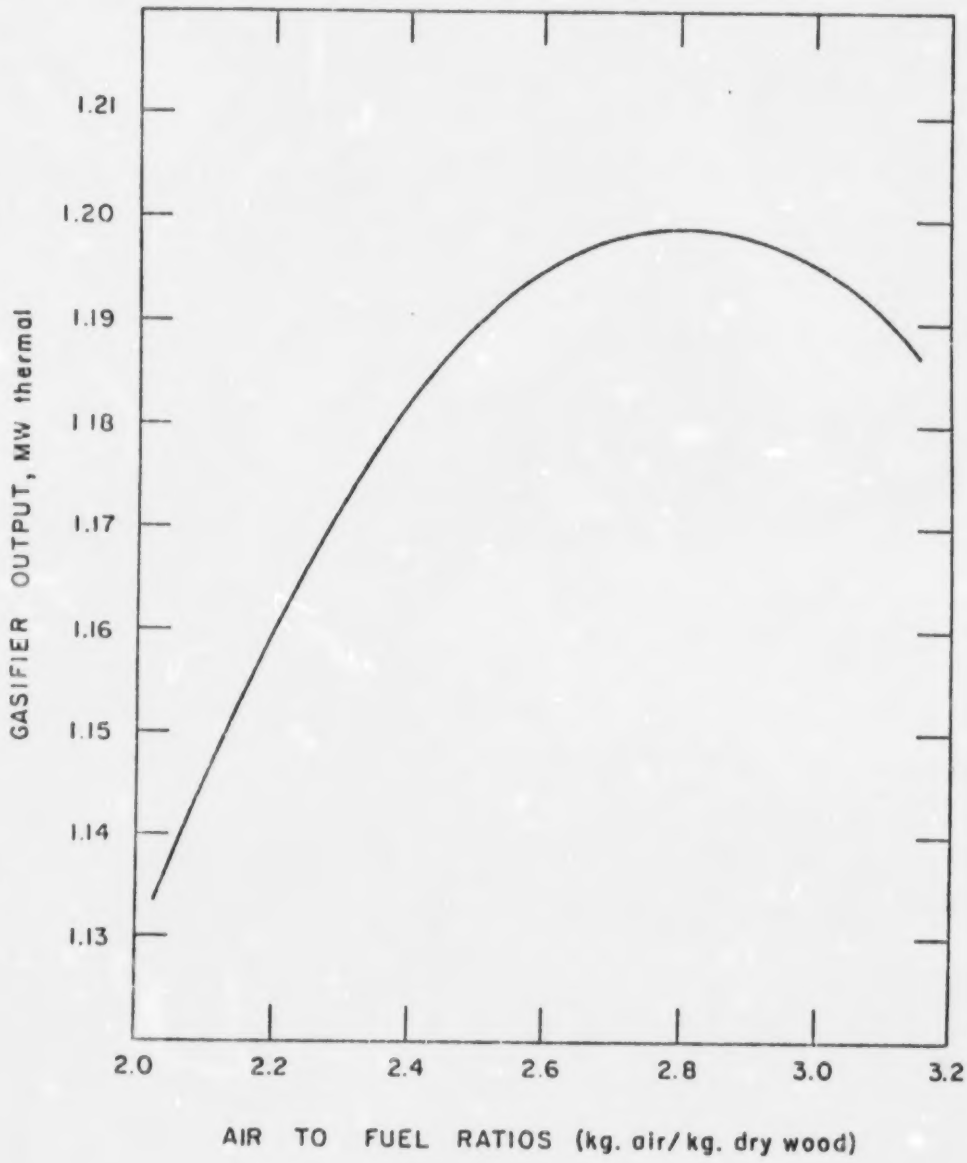

Figure 5. EFFECT OF AIR TO FUEL RATIO ON GASIFIER OUTPUT (calculated)

approximation of actual values.

The data show a general trend of maximal heating values for air to fuel ratios between 2.0 and 2.7, with values dropping quite markedly below or above this range. This behaviour is in general agreement with that reported previously (Weisgerber, 1980).

The relationship between feed type and moisture content versus gas heating value, particulate, tar and moisture content was previously studied in several runs. Trends noted in these runs indicated that a high moisture content feed produced a wet and dirty product gas. No correlation could be seen to hold between feed moisture and product heating value, although theoretical considerations of the water-gas shift reaction would tend to indicate otherwise.

The feed moisture content had a strong effect on the reduction zone and freeboard temperatures, but no noticeable effect on the combustion zone temperature. It was concluded that a moisture content of 40 percent by weight in the feed should not be exceeded for adequate performance of the gasifier. For this reason, the wood chip pile was covered with a water impermeable tarpaulin (which maintained the moisture content in the 30-35 percent range) after being sun-dried to desirable moisture levels.

A general trend indicated with feed moisture in the present study is that drier feeds produce gas with higher heating values, the highest value (6.04 MJ/m^3) being produced from the driest feed tested (23.8 percent moisture), and the lowest (3.58 MJ/m^3) coming from the wettest feed for which a gas analysis was obtained (38 percent moisture). Other factors such as air to fuel ratio

influence this behaviour as well; however, the trend coincides with that reported by Weisgerber.

Spruce and aspen chips (6 x 50 x 25 mm), spruce planer shavings (less than 1 mm thick) and aspen hog fuel (stringy bark strips of 20 x 3 cm mixed with wood slivers of about 6 mm diameter) were used as the feed in several gasifier tests. No significant effects of fuel type on gas heating value were noted. However, fuel size caused marked changes in the performance of the cleaning train, with the hog fuel and shavings being responsible for more than twice as much particulate as for the wood chips (at similar gasifier exit velocities). Concerning condensible hydrocarbons, no correlation was seen with respect to type and size of feed.

Feed (dry) figures for the present study are based on an analysis of bulk density by SPC which showed a value of 135.6 kg/m^3 for wood chips with 7.5 percent moisture, corresponding to 125.4 kg/m^3 for bone dry wood chips. The same analysis indicated a heating value of 19.15 MJ/kg and an elemental analysis of C = 48.28 percent, H = 5.84 percent and N = 0.06 percent, the remainder being oxygen, all on a moisture-free basis.

Failure Analysis

Of the 15 runs performed in the present study, an analysis shows that 45 percent were terminated due to severe smoke leakage, 25 percent due to centrifugal tar extractor problems, 15 percent due to overheating problems, the remainder being planned shutdowns at the end of the working day. These figures, however, are not representative of the severity of the various

problems. While centrifugal tar extractor problems caused 4 shutdowns, this is not considered as severe a problem as overheating, which resulted in 2 shutdowns. Further experimentation would have corrected the tar extractor problem by either determining a workable water flowrate, or by some other method. The overheating problem can only be corrected by an overall redesign of the gasifier.

The 7 runs terminated by smoke leakage adequately indicate the seriousness of this problem. While the problem could be tolerated temporarily by having the gasifier resited away from the SFPC plant, this is not a solution. Other measures must be taken, involving a redesign of the feed system.

Appendix C contains several photographs illustrating the modes of failure indicated above.

Plant Emissions

Air

Excess product gases from the gasifier are flared in a specially designed hood with a 58 kW pilot diesel oil burner. The hood directs the combustion products to the stack, extending about 9 m above the flare system. In 1979 September, Saskatchewan Research Council analyzed the stack gases for particulate, condensible hydrocarbons and moisture. In addition, an analysis was carried out as to NO_x and SO_2 content. The results of these analyses appear in Tables 1, 2 and 3. It is seen that, with the entire output of the plant being burned in the flare, a total of 1.37 kg/h of emissions (1.16 kg/h

Table 1. STACK EMISSION DATA

Gasifier Operating Data	
Feed Type	Spruce Chips and Shavings
Feed Moisture Content	41 percent (total weight basis)
Gasifier Load	0.93 MW (thermal)
Air/Fuel Ratio	2.83 (kg air/kg dry wood)
Sampling Data	
Total Time	30 minutes
Total Volume	0.1687 $m^{3(a)}$
Gas Temperature	996 K
Gas Velocity	14.1 m/s
Gas Moisture Content	28 percent (volume basis)
Emission Data	
Stack Gas Flowrate	1240 m^3/h
Total Emission	1.37 kg/h
Particulate Concentration	0.93 $g/m^{3(a)}$ (1.16 kg/h)$^{(a)}$
Condensible Hydrocarbon Concentration	0.17 $g/m^{3(a)}$ (0.21 kg/h)$^{(a)}$

(a) Dry, NTP Basis

Table 2. PARTICLE SIZE DISTRIBUTION

Particulate Size	Weight Fraction (%)
>10	40
5 - 10	23
0.3 - 5	17
<0.3 *	20

* 75.6 percent of which is condensible hydrocarbons.

Table 3. STACK GAS COMPOSITION

Gas Analysis	Volume Percent (Dry Basis)
CO_2	16.0
O_2	5.1
N_2	78.9
NO_x	0.01
SO_2	Less than .025[a]

[a] Based on 0.2 percent sulfur in wood.

particulates and 0.21 kg/h condensible hydrocarbons) were detected. The tars, although produced in minor amounts, could be burned for process heat, as the heat of combustion was measured as 36 MJ/kg, with a sulfur content of 0.32 percent. Although no set legislation now exists in Saskatchewan as to what is an acceptable emission rate with respect to air pollution standards, the Saskatchewan Department of the Environment has estimated that, judging by the temperature (723°C) and velocity (14.1 m/s) of the stack gases, dispersion would be fast, and no problems should be encountered. In a commercial plant of 5 to 10 times the size, the stack might have to be heightened, however.

The concentrations of NO_x (0.01 volume percent) and SO_2 (less than 0.025 volume percent) are judged low enough to not require post-treatment.

Water

The total effluent water from the gas cleaning train has been measured at 2.1 m^3/h. This low value results from the low flowrates acceptable to the centrifugal tar extractor, which tended to stall at higher rates. Table 4 lists the results of analyses performed by the Saskatchewan Research Council (1981 November 02) for phenols and total organic carbon, and by the Saskatchewan Power Corporation (1981 December 14) for pH on effluent water at various stated points in the cleaning train. Comparing samples 1 and 3 gives an indication of the efficiency of the tar extractor, which has removed more than one-half the phenols and two-thirds the TOC entering it. A look at samples 1 and 2 suggests that the tar/water separator, while it does allow settling of the tar, is also allowing sufficient contact time for some of the

Table 4. EFFLUENT WATER ANALYSIS

Sample No.	Phenols, g/mL	Total Organic Carbon, percent by weight	pH
1	52	0.18	4.2
2	104	0.53	2.9
3	125	0.52	3.2
4	818	6.0	2.9

Identification of Samples:

1. Combined effluent from scrubber and centrifugal tar extractor, previous to installation of tar/water separator (1981 07 01).

2. Effluent from tar/water separator (1981 08 11).

3. Effluent from scrubber tank (1981 08 11).

4. Product water obtained from stack sampler located previous to the cyclone (1981 07 22).

phenols contained in the tar to be leached out by the water phase. Other methods of tar/water separation will have to be considered.

Sample 4 shows the phenols and TOC for the undiluted product water from the gasification process, previous to any treatment and indicates the worst possible water emissions in the event that the water supply to the scrubber and centrifugal tar extractor fails, while the gasifier continues to operate. It must be realized that for a typical feed rate of 250 kg/h of dry wood, the water contained in the feed (at 35 percent moisture) is only 0.09 m^3/h, and despite the relatively high phenols concentration (818 ppm), it would pose no serious threat to the environment. If the water supply to the cleaning train did fail, the diesel engine would probably stall, as the gas feed would be too hot and tarry to combust properly.

The Saskatchewan Department of the Environment states that effluent can be disposed of into a body of water if the total concentration of phenols in the receiving body does not exceed 0.005 mg/L. Thus for the general case, a dilution of 10 to 20 would be required to safely dispose of the plant effluent. This would require a creek with a flowrate of at least 42 m^3/h, which is a very slowly flowing body of water. They also state that the dissolved oxygen in the receiving body should not drop below 5 mg/L. Some Saskatchewan water bodies are naturally below this value, so aeration would probably be required to meet this criterion.

The pH data presented in Table 4 indicate that the effluent water from the gasification process is quite acidic. However, for reasons stated above with respect to effluent quantity, this acidity should pose no problem.

Ash

Table 5 reports elemental analyses for ash samples collected from different points of the wood gasifier system. Sample 1 indicates an analysis of negligible amounts of C, H, N. This clinker was formed mainly from sand introduced into the system with the wood chip feed. For a clean feed, very little clinker will be formed. Sample 2 is ash collected below the gasifier, and the low value reported for C indicates a high gasification efficiency. This ash is produced at the rate of about 1-2 kg/h for a typical feed rate of 250 kg/h of dry wood. This ash could be utilized as a fertilizer, or could be buried, producing no environmental concerns. Sample 3 comes from the ash box below the cyclone. The higher C content is expected in this sample, as the lighter carbon particles would be carried over in the gas phase. The amount collected, however, only a few kilograms throughout the entire Phase IV operations, suggestes that this ash poses no threat to the environment. It also suggests that the present cyclone is grossly oversized for the current plant.

In summary, the gasifier effluents, even if scaled up 5 to 10 times, appear to pose no serious problems to the Saskatchewan environment.

Table 5. ASH ANALYSIS

Sample No.	Elemental Analysis, percent by weight C	H	N
1	0.02	--	--
2	3.33	0.08	--
3	19.42	0.24	0.01

Identification of Samples:

1. Clinker from gasifier floor (1981 09 15).

2. Ash from gasifier ash box (1981 07 15).

3. Ash from cyclone ash box (1981 09 15).

A DISCUSSION OF PROBLEMS ENCOUNTERED

Three main categories of problems were encountered during this phase of operations: a) general electrical-mechanical maintenance problems which would be present and expected under normal operation; b) problems associated with feeding into a positive-pressure system; and c) problems associated with the inability to fluidize the feed.

General Maintenance Problems

A number of breakdowns were encountered, which fall into this category. Tar buildup was noted in the butterfly valve above the cyclone, in some of the manometer lines, and in the sampling orifices. Severe tarring occurred in the flare burner, as the product gas is uncleaned as it enters the flare. The burner motor, electrodes and heat sensor had to be replaced, and tarring is suspected as a possible cause for these failures.

A water valve was accidentally turned on during a plant shutdown. By the time it was noticed, the cyclone, scrubber, centrifugal tar extractor and coke block dryer had been filled with water. In draining these units through the scrubber box, a large amount of tar, upwards of 100 kg, exited with the water. It is thought that the tar was a deposit, built up over three years of testing, on the walls of the cyclone. The cyclone is without an access port, while the scrubber box has a cleanout door and had been previously inspected. The tar extractor had shortly before been taken apart to replace the bearings and the coke dryer had its load of wood blocks replaced at the same time.

As the line to the cyclone is now well insulated, tar buildup must have developed in the cyclone in runs from previous years, and this source of tar is no longer a problem. The incident does, however, emphasize the need for an inspection port in the cyclone.

In the hydraulic system a pump coupling disintegrated causing a system shutdown. The new coupling is functioning well and no further problems are expected. The breaker in the hydraulic system has tripped repeatedly; however, this was not a fault inherent in the system. Rather it was the fault of the feed conveyor system. As wood chips sometimes missed the airlock opening, they were dragged back by the returning conveyor, stalling the hydraulic system. This problem has been partially overcome, as discussed previously.

A motor burned out on the centrifugal extractor, bearings wore out, and the circuit breaker tripped repeatedly. All of these problems stem from the water level and flowrate in the centrifuge, and are capable of being corrected.

Control circuitry in the Maxon burner had to be replaced at the beginning of this phase of operations. Once replaced, the Maxon provided trouble-free operation throughout the testing.

Minor maintenance was performed on the rupture disc which leaked periodically, on thermocouples which leaked at the fittings, and on the feedscrew motor base which was damaged in a fall during maintenance on the airlock.

Chip Feeding Problem

In this category definite equipment problems existed, although some of the trouble was site-related. The most severe problem encountered was the inability to satisfactorily seal the system. Barring other breakdowns, this failing could have been tolerated long enough to achieve a continuous run, were it not for the location of the pilot plant. Our plant was situated about 10 m south east of a set of large, sliding double doors into the plywood plant, and about 20 m due east of a fresh air inlet duct for the plant. Wind direction was highly unpredictable in the immediate area. On several occasions we were either asked to shut down by plant personnel or chose to do so on our own accord, in order to preserve amicable relations with Saskatchewan Forest Products Corporation.

Smoke leakage was quite severe through the newly installed airlock, more so when the grate was installed above the ash scraper (as this placed the bottom of the bed at the level of the feedscrew entrance, providing no resistance for the combustion air and gases). Attempts to alleviate the problem (rubber vanes, compressed air injection, and a suction line, as previously discussed) were only partially successful. The problems were compounded by the fact that after the airlock had been installed on site it was found that the floating seal had been factory-installed upside down, and in this position, was serving no useful function. Modifications were made, and the airlock was reinstalled in an inverted position.

Once the vanes were ground down and substituted with rubber blades (it was discovered that, although assured by the manufacturer, Joy Manufacturing Company, that the airlock would operate satisfactorily with a wood chip feed, it was intended for a fine, granular or powdery feed, such as fly ash) to allow feeding to take place without breaking shear pins, another problem arose. The rubber blades had a service life of less than a week before replacement was required. Due to awkward working conditions the easiest way to replace the blades was to remove the airlock to the ground. This required dismantling of several pieces of heavy equipment. Despite these measures, the gasifier could be operated only when the wind blew away from the plywood plant.

The flighting on the gasifier end of the feed screw was damaged on two separate occasions (possibly due to a foreign object, or to excess heat, as discussed below), and the bearings had to be replaced once. Aside from these incidents, the feed screw provided trouble-free operation.

Bed Fluidization Problem

A problem area recognized in earlier phases of the project was the lack of fluidization in the gasifier bed. The gasifier design was based on the premise that the wood chip feed would be in a fluidized state, thus ignoring the inherent difficulty in fluidizing a non-spherical particle such as a wood chip. A relatively simple analysis reveals that a single, typical wood chip requires a superficial minimum fluidizing velocity of about 0.9 to 1.5 m/s. In the actual case where many chips are present, collisions and overlapping must be considered and the required fluidizing velocity becomes much greater.

The combustion air blower is designed to supply 12 m^3/min, which translates, for the 1.22 m internal diameter of the gasifier, to a superficial velocity of 0.17 m/s. In the best case then, it appears to be undersized by a factor of 5, and in actual terms that factor is probably 20 to 30.

This phase of the project was an attempt to modify the pilot plant for operation in the fixed bed mode. The lack of fluidization (recognized earlier) was the direct cause of several severe problems, outlined below.

Deterioration of the ash scraper arm, and its failure to turn were noted in the previous phase of the work. It was determined that the load of wood chips (about 1 m in depth) was too heavy for the motor to overcome, but, as discussed previously, a replacement motor of the required size would lead to other problems.

In the fixed-bed mode of operation combustion takes place in a localized zone. Deterioration of the ash scraper was as a direct result of its location in the combustion zone. It was thought that, by adding a protective grate above the ash scaper, the two problems, overheating and overloading, would be solved. But this solution led to other problems. The position of the feedscrew entrance at the level of the top face of the new grate resulted in the protective layer of ash and clinker being scraped by incoming wood chips. The overall result was an overheating of the end of the feedscrew and of the portion of the grate near the feed entrance.

Although in theory combustion air flowrate could provide a control of the bed temperature, in practice it was only a very crude control. In a fluidized bed, the flowrate would determine the bed height and density, and the residence time in the gasifier. In a fixed bed, no such control was possible as reaction zone temperature was relatively insensitive to air flow. At high flows, the temperature often exceeded 1200°C. Upon cutting off the combustion air, the temperature would drop to 500-600°C very rapidly, as the feed would become oxygen-starved, and combustion and gasification would cease. Raising the flowrate would recommence combustion, and the temperature would once again rise quickly above 1200°C. Reduction of the air flowrate had no immediate effect on the bed temperature, which dropped very slowly. However, the quality of the product gases deteriorated badly in these instances. Thus air flowrate acted as an on/off switch rather than a rheostat, which would be the preferred mode of operation.

ECONOMIC ANALYSIS

Appendix D contains a comparison of the electrical generation costs for a diesel engine/generator set versus a wood gasifier equipped with two modified dual fuel diesel engine/generator sets (identical to the set now on the site) to handle the capacity the gasifier is capable of. The load factors chosen are equivalent to operation of 300 days per year, with the diesel operating continuously and the gasifier operating 12 hours per day. Overall efficiency figures are based on past experience with this type of equipment. It is felt that manpower is not required to run the diesel, with maintenance (4 percent of capital cost) during down time being sufficient. For the gasifier, however, 2 man-years have been assigned, as there is a constant need for someone to load the feed, and it is felt that the expected maintenance will be more manpower-intensive than for the diesel. In addition, it is felt that, with the expected maintenance, there will be a need after 10 years for major equipment repair or replacement, such as relining the gasifier, replacing piping, and the like, and this has been provided for in the amount of $50,000 allocated to upgrading. (Table 6 is a compilation of the factors considered in the economic analysis, and lists the assumptions on which it is based.)

For the gasifier, two cases are evaluated: Figure D1 where wood waste is available at no charge, for example, having the gasifier sited at a pulp and paper or plywood and lumber operation; and Figure D2, representing wood at a

Table 6. ECONOMIC ANALYSIS OF WOOD GASIFIER-MOTOR-GENERATOR VERSUS DIESEL ENGINE-GENERATOR ELECTRICITY PRODUCTION -- BASE CASE

	Wood Gasifier with Two Engine/Generator Sets	Engine/Generator
Capital Cost (1981 $)	278,300 + 132,600 Total = 410,900	66,300
Service Life (years)	15	15
Upgrading Requirement	after 10 years $50,000 (1981 $)	--
Nominal Electrical Capacity (kW(e))	300	150
Overall Efficiency (%)	14	30
Load Factor (%)	40	80
Actual Electrical Capacity (kW(e))	120	120
Manpower Requirement	2	--
Maintenance (per year)	4 percent of Capital Cost	
Levelized Cost of Produced Electricity (cents/kWh)	12.1	10.5

Basis of Calculations:

1. Labour rate is $18,000 (1981 $) per man-year.
2. Capital costs (1981 $) are factored estimates using 1981 June Plant Cost Index from Chemical Engineering, and original installed equipment cost figures.
3. Payback period on capital investment is 7 years. On the upgrading costs, payback is over a 5-year period.

Table 6 (Cont'd.) ECONOMIC ANALYSIS OF WOOD GASIFIER-MOTOR-GENERATOR VERSUS DIESEL ENGINE-GENERATOR ELECTRICITY PRODUCTION -- BASE CASE

4. Depreciation is straight-line over a 10-year period. On the upgrading costs, depreciation is straight-line over 5 years.

5. The tax rate is 50 percent.

6. The interest rate is 15 percent over the life of the plant.

7. The discount rate is 14.5 percent.

8. The escalation rate is 12 percent on wood, maintenance and manpower, and 18 percent on diesel fuel for the first 5 years, then 12 percent for the remaining 10 years.

9. Neither plant has any salvage value after 15 years.

10. Diesel costs $0.33/L (1981 $). This is the average off-road price for isolated northern Saskatchewan communities.

11. Heating value of diesel fuel is 44.3 MJ/kg (40.8 MJ/L).

12. Wood (aspen poplar) has a heating value of 20.2 MJ/kg (bone dry).

13. Fuel requirements per year: Gasifier -- wood 1190 t, diesel fuel 72.8 m^3 (11 percent); Engine/generator -- diesel fuel 488 m^3.

14. Wood costs $25 per oven dried tonne (1981 $).

15. Calculated levelized costs are in constant 1981 $.

cost of $25/ODt (oven dried tonne). Figure D3 brings these two cases together in a sensitivity analysis based on the cost of wood. Figure D4 looks at the diesel engine/generator production of electricity, with diesel fuel assumed to escalate at 18 percent annually for 5 years, then at 12 percent annually for the remaining 10 years. A point is included showing the levelized production cost for an 18 percent annual escalation throughout.

Figure D1, the gasifier with free wood case, indicates that the process is operating cost (O_T) sensitive, with the production cost increasing six-fold over the sensitivity range considered, and is less sensitive to capital cost (only a two-fold increase over the range). As expected, cost is sensitive to load, but the base case load is probably the only practical level of operation.

In Figure D2, with wood at $25/ODt, the capital and load lines are the same as in Figure D1, but they have been displaced upward on the cost axis. The operating line is steeper, with an eight-fold increase over the sensitivity range.

The sensitivity analysis based on the cost of wood, Figure D3, reveals that gasification is relatively insensitive to wood cost, as the electrical production cost increases by less than a factor of two between free wood and wood at $75/ODt. The effect is diluted by the cost of diesel which in 1981 $ accounts for almost one-half the gasifier fuel costs.

The diesel engine/generator case, in Figure D4, indicates an almost flat capital line, but a steeply sloping operating line, increasing about forty-fold over the sensitivity range considered. This infers that the equipment cost is minimal compared to the cost of diesel fuel.

Comparing the two production plants, it is observed that the cost of diesel-produced electricity exceeds the cost of wood-produced power only for a wood cost of less than $8/ODt. To determine the availability of wood at under $8/ODT would require a costly market survey. But several points are obvious. First, the costs of harvesting wood exceed $8/ODt; therefore, wood cannot be cut down to be used specifically in a wood gasification unit. Wood waste only should be considered. Second, large wood waste surpluses exist in B.C., Ontario and Quebec. There is no surplus in Saskatchewan. A plant of this nature would have to be sited at the source of waste wood, such as at the present Hudson Bay location. Third, the cost of waste wood expands to whatever price the market will bear, and market conditions are not easily predictable. This implies that the wood gasifier-motor-generator route would be practical only if a free source of wood waste were available. The most favourable scenario would be the operation of the plant by the waste wood producer. Where a charge for waste disposal was normally levied, this cost would be handled as a credit to the electricity production cost.

It should be pointed out here that the levelized costs referred to in Figures D1 to D4 have been calculated using constant 1981 $. To obtain the

more widely understood levelized cost in constant dollars over the life cycle of the plant one must multiply the levelized costs reported here by the factor $n \Big/ \sum_{i=1}^{n} \frac{1}{(1+d)^i}$ where d is the discount rate as a decimal, and n is the number of years of plant life under consideration.

CONCLUSIONS AND RECOMMENDATIONS

The results of work performed in the previous phases have indicated several areas of difficulty in the scale-up of wood gasifiers operating on chips or hog fuel. The principal conclusions related to the operation of the Hudson Bay Plant are:

1) It was found in earlier phases of the work that, because of inappropriate scale-up of the gasifier, fluidization could not be achieved, leading to several operational difficulties, for example, leakage of gas through the feed system, ash removal problems, etc. Steps taken to overcome these difficulties by operating the unit in a fixed-bed mode led to other difficulties which prevented continuous operation.

2) Stack gas and wastewater effluent pose no serious threat to the environment, and could be safely disposed of in Saskatachewan without producing pollution problems. A simple settling tank to separate the tar component from the wastewater was found to be inadequate, as phenols are leached from the tar by the water during the settling process. Despite this problem, phenols levels are not too high to prevent safe disposal.

3) Providing a source of wood at under $8 (1981 $) per oven dried tonne is available, the production of electricity from wood gas will be a viable alternative to diesel engine-generator electricity production over the next 15 years. Market indicators would suggest that wood could not be harvested for gasification for under $8/ODt. This means that only waste wood can be considered as a gasification feed. The scenario with the best chance of success would be operation of the plant by a waste wood

producer, who would gain an additional credit to the cost of electricity production in the case where a charge was normally levied for waste disposal.

Both approaches to the gasifier design--fluidized bed and fixed moving bed--are feasible. It is estimated, however, that modifications necessary to run the plant in a continuous mode could easily exceed the original capital investment.

Regardless of which gasifier design is to be considered, extensive modifications are required to the gasifier feed system, air blower and ash removal system. The following modifications, specific to the gasifier design, have been identified during the course of this work as being necessary for reliable operation.

If the gasifier is modified to operate in the fluidized mode, means must be provided to supply the fluidization medium (sand), appropriate distributor plates and caps, internal cyclone, solids recycle and addition lines and hopper, larger blower, etc. If operated in a fixed moving bed mode, the ash removal and grate system should be replaced by a conical (apex facing upward), rotating grate covered by several centimetres of ash. Feeding would be from the top of the gasifier, and the internal diameter would have to increase slightly in the downward direction to prevent bridging of the wood chips. A system of two airlocks and two feedscrews could be utilized to prevent gas leakage. Alternatively, to prevent the shear pin problems encountered due to

the inability of the airlock to shear the wood chips, a system of two pressure sealing ball valves could be employed, with nitrogen pressurization in the area between the valves to assure no gas leakage would occur.

Other relatively minor modifications should be considered as well. Stalling of the centrifugal tar extractor could be overcome by installing a dedicated water supply. It is felt that the stalling problem stemmed from variations in water pressure due to intermittent water use in the plywood plant. Stalling of the hydraulic feeding system was caused by wood chips missing the airlock entrance and being dragged back by the returning conveyor belt. Correction of this system would become unnecessary were the feed system redesigned as outlined above. Alternately, a larger airlock in the present set-up would solve this problem.

The question of which gasifier design is preferable for wood feed has been raised. Advantages and disadvantages exist with both systems, such as the following: fixed moving bed gasifiers, due to the countercurrent direct contact heat exchange that takes place, have a relatively high conversion efficiency with a minimum of heat loss. A limitation is in the use of wet or very fine feeds, which tend to bridge or to clog the bed, resulting in channeling, and inefficient conversion. Fluidized beds provide good mixing of the solids, a uniform temperatue bed, and rapid temperature equilibration between the solids and gases. However, they suffer from the same agglomeration problem as do moving beds, with the particle size increasing, and the larger particles collapsing the bed. Other disadvantages include carryover of solids in the product gas, which must be dealt with, and their higher capital cost (Probstein and Hicks, 1982).

Despite all that has been said in this report, the choice between fixed and fluidized bed gasifiers still requires a careful evaluation for each specific situation. Type of feed and amount available, site, and the skills level of the workforce all must be considered.

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1. Probstein, R.F. and Hicks, R.E., "Synthetic Fuels", McGraw-Hill, New York, N.Y., 1982, pp. 148-153.

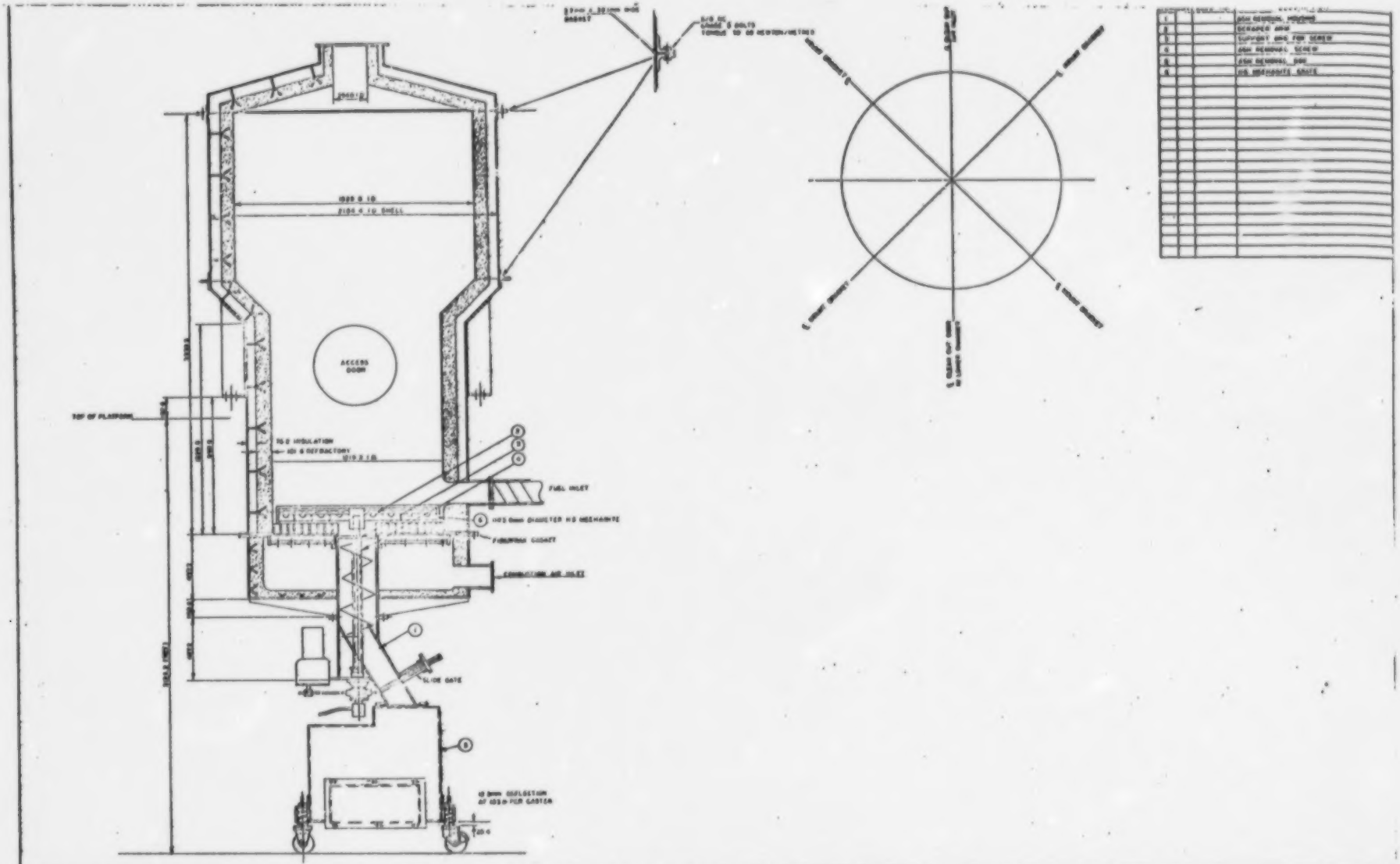
2. Saskatchewan Power Corporation R & D Report No. 4476-1978-1-Alternate Energy "Evaluation of the Saskatchewan Power Corporation Wood Gasifier at Hudson Bay, Saskatchewan 1978-79", (1979 May 24).

3. Stobbs, R. A. and Verma, A., "Wood for Power Generation in Isolated Northern Communities", Saskatchewan Power Corporation R & D Report No. IE10-5776 (1977 August 17).

4. Weisgerber, G. A., "Pilot Plant Investigation of the SPC Wood Gasifier at Hudson Bay -- Final Report", SPC Report No. 4406-1979-2-Alternate Energy (1980 June).

APPENDIX A

Drawings of Modified or New Equipment



1		ASH REMOVAL HOUSING
2		SCRAPER ARM
3		SUPPORT ARM FOR SCREW
4		ASH REMOVAL SCREW
5		ASH REMOVAL PAN
6		ASH DISCHARGE GATE

SASKATCHEWAN POWER CORPORATION

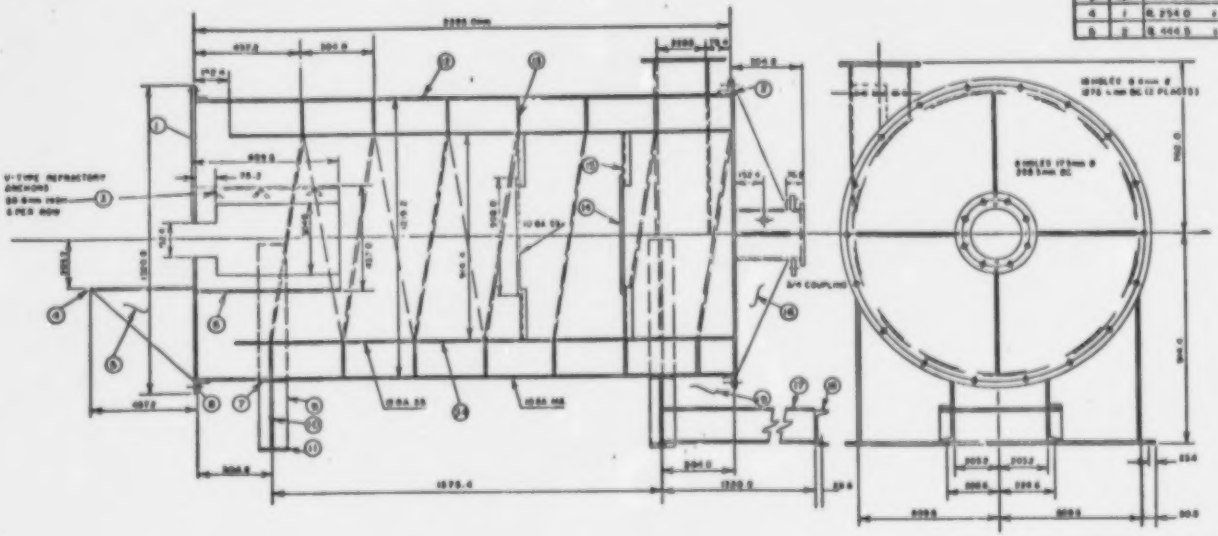
SUB ASSEMBLY

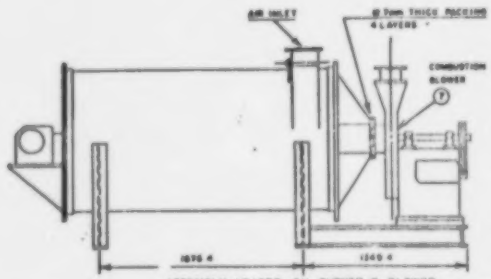
Ø19.2mm DIA. GASIFIER

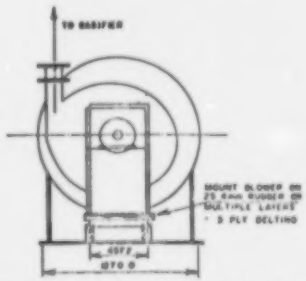
EXPANDED FREEBOARD MODEL

MATERIAL LIST

ITEM	QUAN.	DESCRIPTION
1	1	C 35 R 320.8 OD x 152.4 ID
2	1	C 35 C 320.8 OD x 203.2 ID
3	10	ROD C 35 OD x 44.5
4	1	R 254.0 x 444.5
5	2	R 444.5 x 635 x 444.5 (SHAPE)
6	1	R 609.6 x 108.6 x 1425.6 (ROLL)
7	8	BAR 101.6 x 6.76 x 190.5 (COLLAR BEND)
8	2	L 50.8 x 6.35 x 50.8 x 3969.3 (ROLL)
9	4	BAR 101.6 x 6.76 x 914.4
10	2	R 914.4 x 6.35 x 1206.5 (SHAPE)
11	2	R 101.6 x 6.35 x 1320.8
12	1	R 2286.0 x 108.6 x 3810.5 (ROLL)
13	6.5	12 GA R 1214.4 OD x 920.810
14	2	C 35 R 508.0 DIA
15	8	L 381.0 x 6.76 x 381.0 x 228.6
16	4	R 228.6 x 6.35 x 482.6 (SHAPE)
17	2	C 152.4 x 209.3 x 1317.6 LONG
18	1	C 152.4 x 209.3 x 508.0 LONG
19	2	R 177.8 x 6.35 x 381.0 (SHAPE)
20	1	R 2113.6 x 1206.5 x 2863.8 (ROLL)







ASSEMBLY HEATER, OIL BURNER & BLOWER

ALL DIMENSIONS AND MATERIALS ARE IN MILLIMETRES

F	E	D	C	B	A
REVISED BY DATE AUTHORIZED BY APPROVED BY	REVISED BY DATE AUTHORIZED BY APPROVED BY	REVISED BY DATE AUTHORIZED BY APPROVED BY	REVISED BY DATE AUTHORIZED BY APPROVED BY	REVISED BY DATE AUTHORIZED BY APPROVED BY	REVISED BY DATE AUTHORIZED BY APPROVED BY

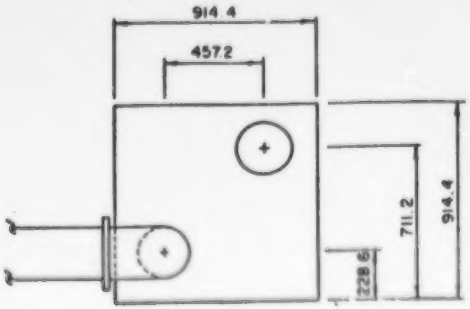
DRAFTING DEPT.
DRAWN BY
CHECKED BY
DATE

DESIGN DIVISION
DESIGNED BY
CHECKED BY
SUBMITTED BY
APPROVED BY
DATE APPROVED

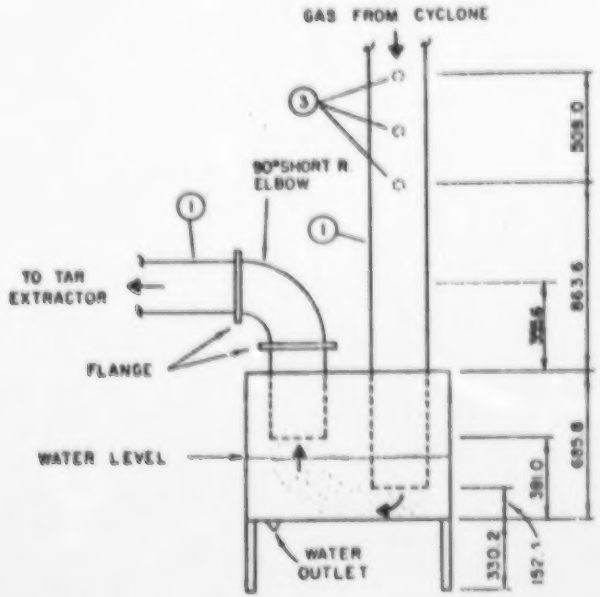
SASKATCHEWAN POWER CORPORATION

AIR PREHEATER FOR GASIFIER

E.O.T. DWG.
F.S.B. REF.
SCALE: NTS
DRAWING No.
SHEET OF
REV.



TOP VIEW



SIDE VIEW

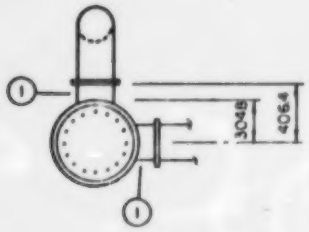
MATERIAL LIST	
NO	DESCRIPTION
1	NPS 10 STEEL PIPE SCH. 40
2	NPS 1 1/4 STEEL TUBING
3	SCRUBBING WATER INLETS 1/2" I.D.
4	SCRUBBING WATER OUTLET TO 1/2 H.P. PUMP

NOTE :

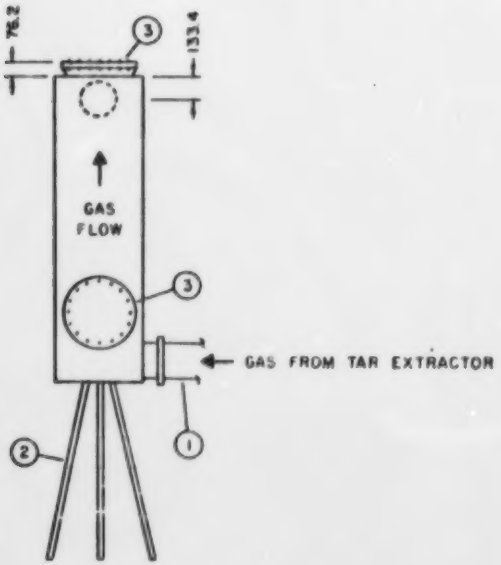
ALL DIMENSIONS ARE MILLIMETRES

SCRUBBER TANK

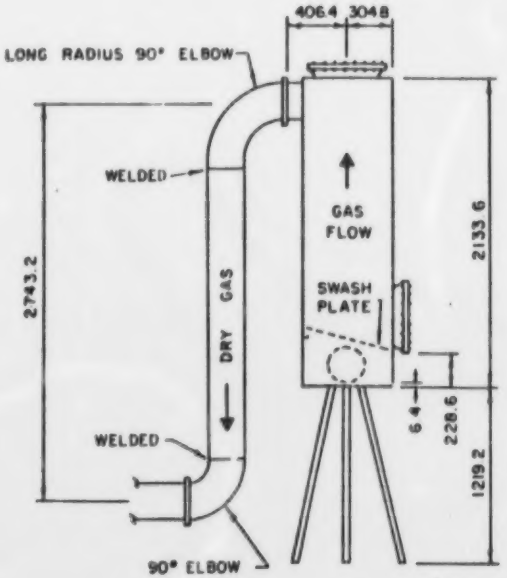
MATERIAL LIST	
NO	DESCRIPTION
1	NPS 10 STEEL PIPE SCH. 40
2	NPS 1 1/4 STEEL TUBING
3	WOOD BLOCK ACCESS PORTS, 6.35mm STEEL PLATE



TOP VIEW



FRONT VIEW



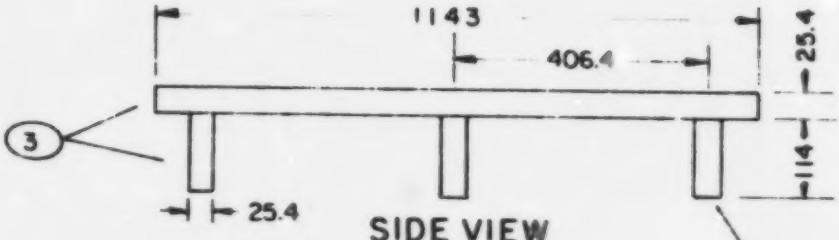
SIDE VIEW

NOTE:

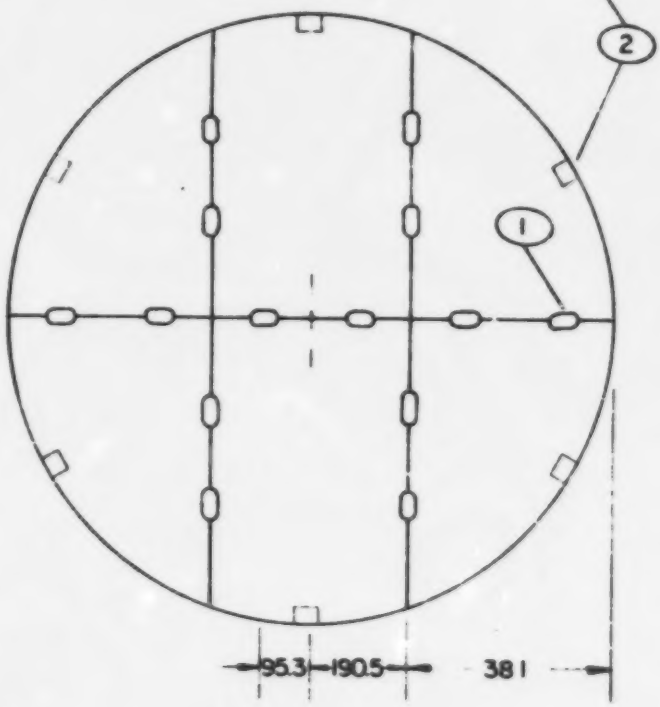
ALL DIMENSIONS ARE MILLIMETRE

DRYING COLUMN

H.S. MEEHANITE GRATE



SIDE VIEW



PLAN VIEW

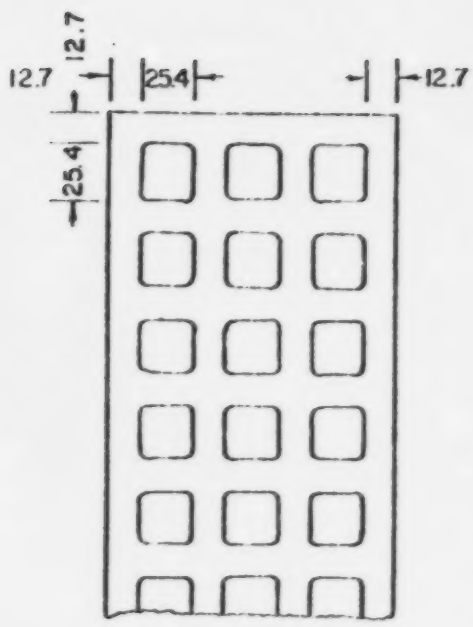
NOTE:

1. 16mm x 25mm OBLONG BOLT HOLES
2. GRATE SUPPORTS (6) 25 x 25 x 114 mm
3. GRATE MATERIAL - H.S. MEEHANITE
4. ALL DIMENSIONS ARE IN mm.

GRATE CAST IN 6 SECTION

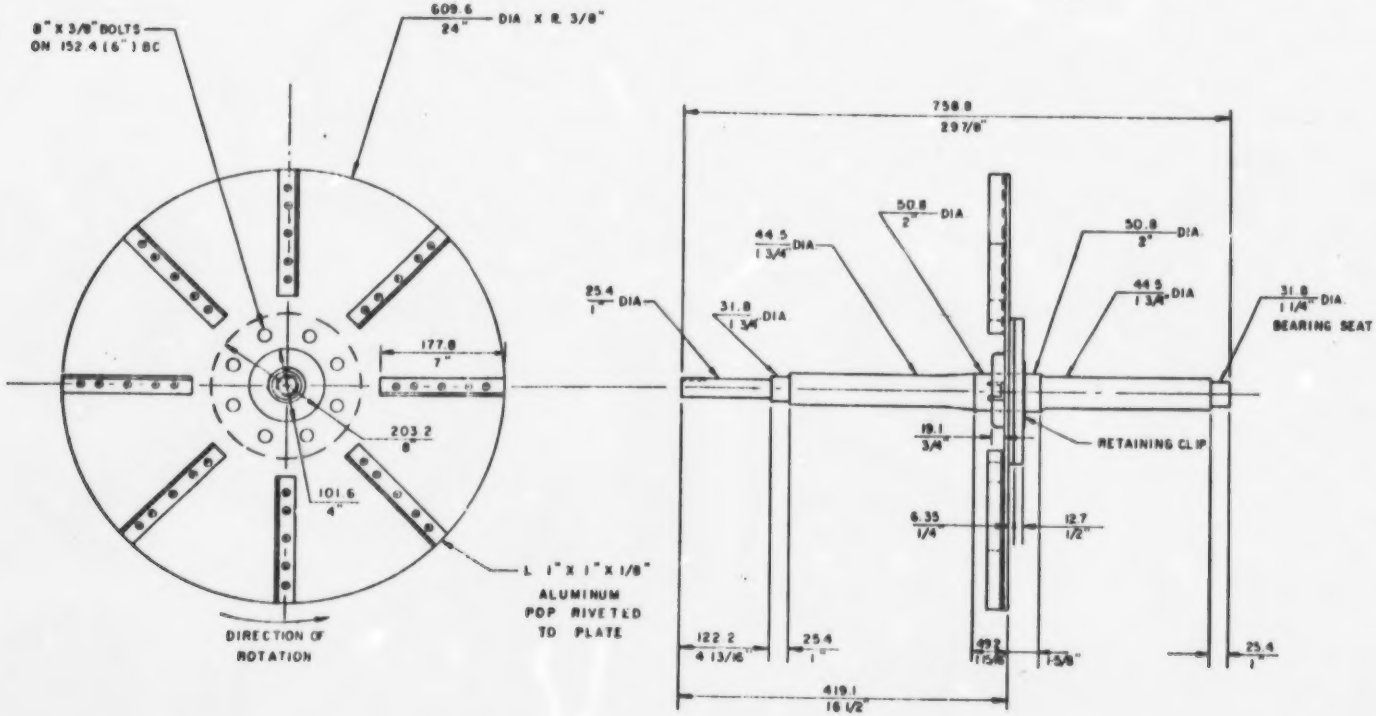
N.T.S.

H. S. MEEHANITE GRATE

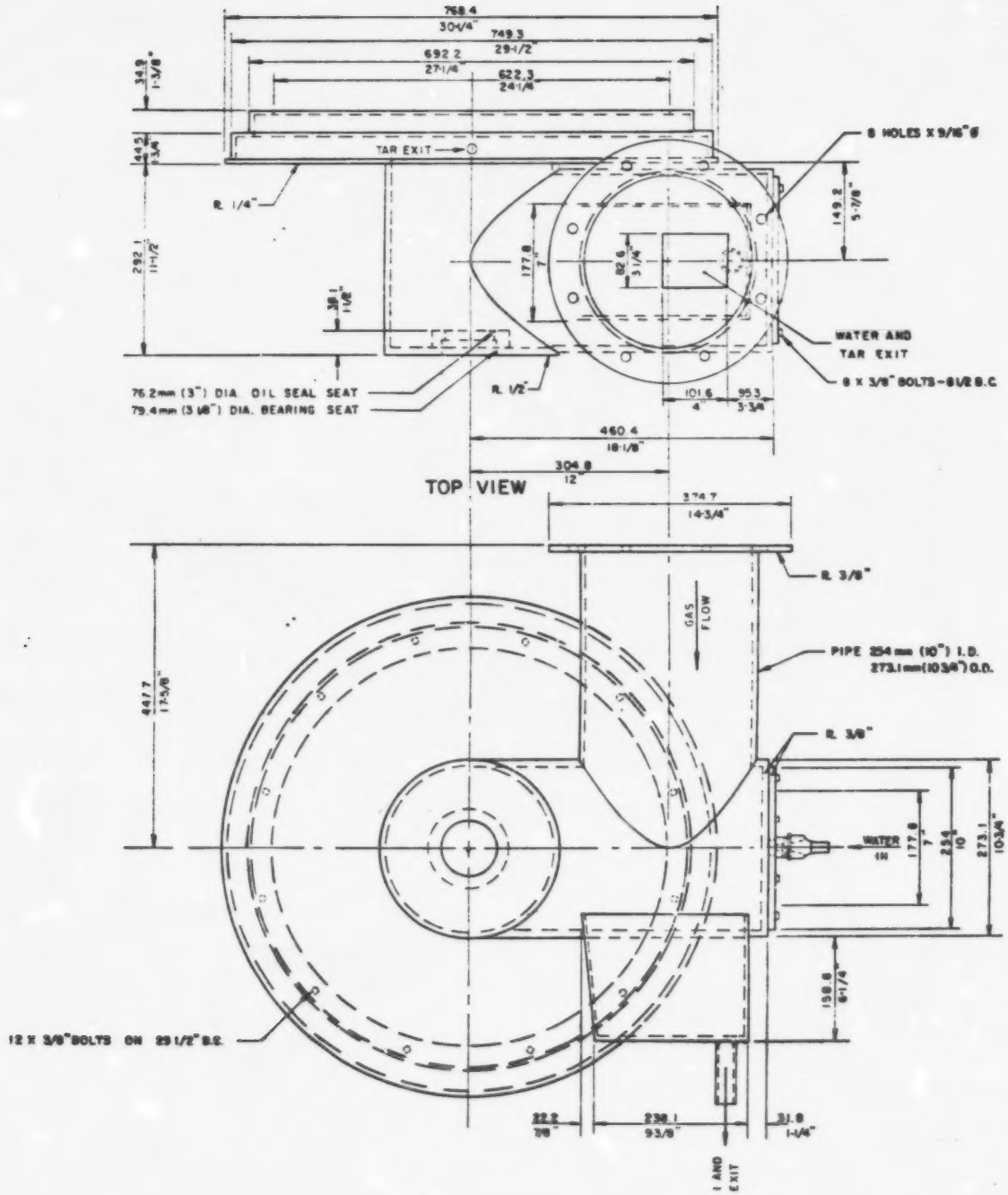


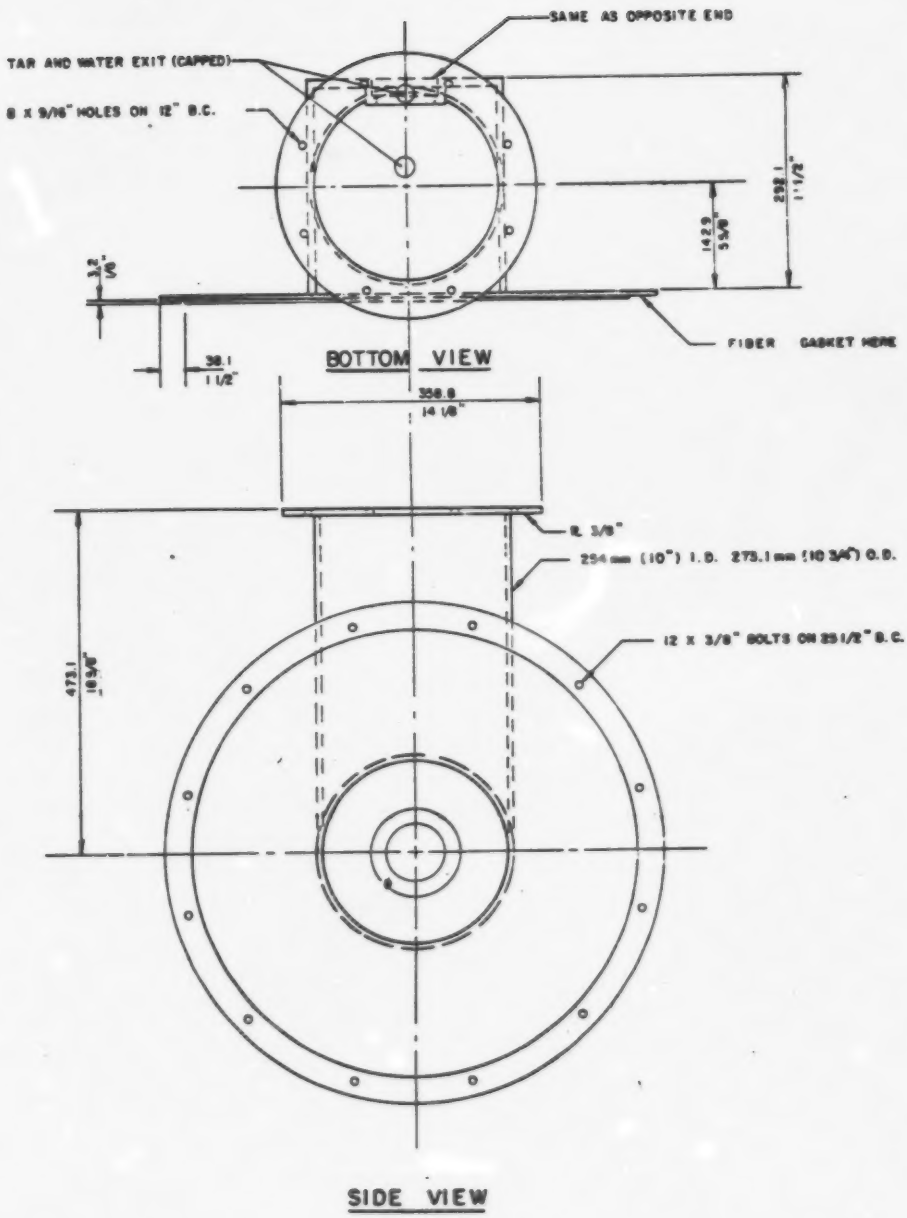
GRATE PATTERN DETAIL

CENTRIFUGAL TAR EXTRACTOR

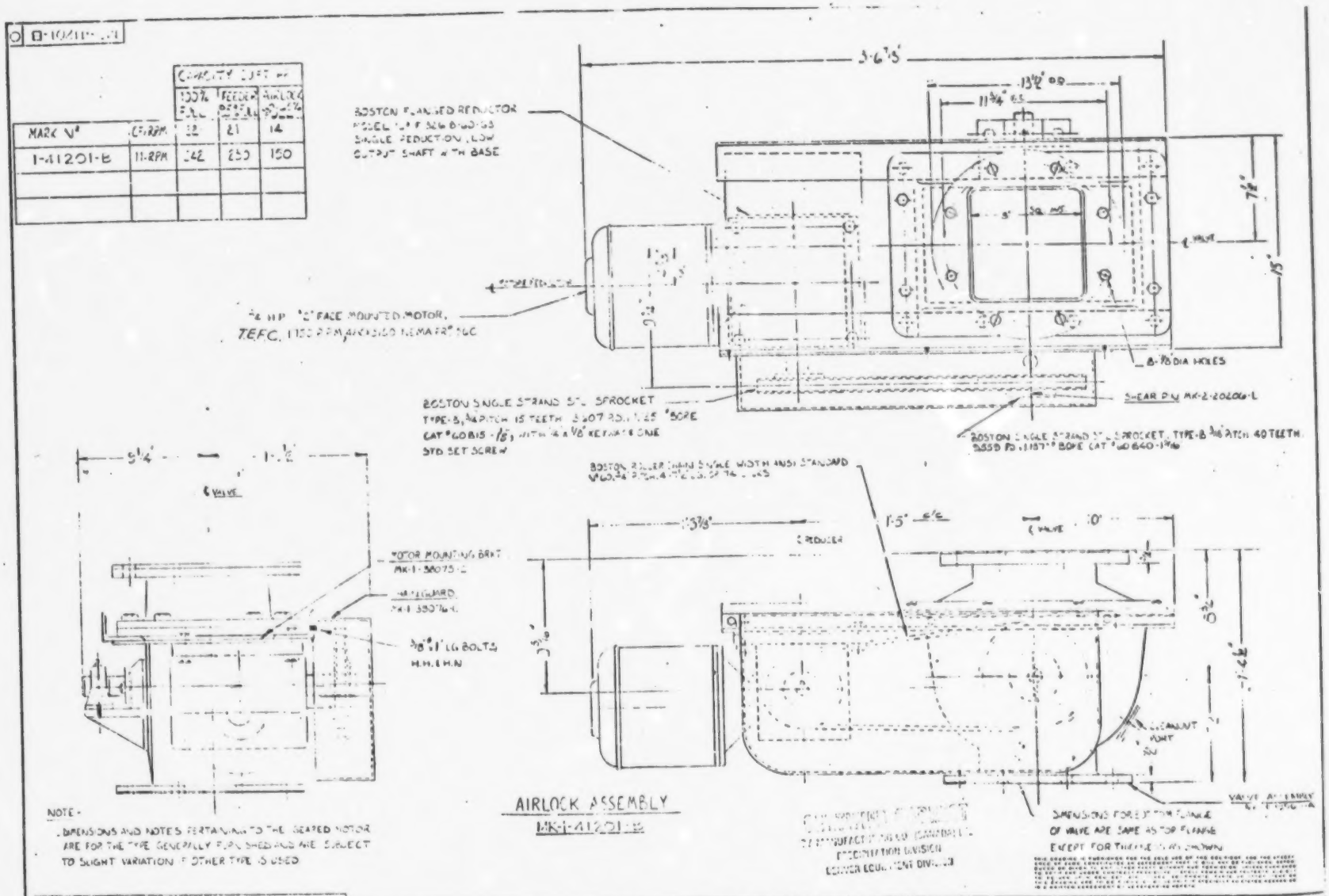


INTERIOR DETAILS


768.4
30-1/4"
749.3
29-1/2"
692.2
27-1/4"
622.3
24-1/8"
34.9
1-3/8"
44.5
1-3/4"
TAR EXIT
8 HOLES X 9/16"Ø
R. 1/4"
149.2
5-7/8"
292.1
11-1/2"
177.8
7"
82.6
3-1/4"
38.1
1-1/2"
WATER AND
TAR EXIT
8 X 3/8" BOLTS-8 1/2 B.C
76.2mm (3") DIA. OIL SEAL SEAT
79.4mm (3 1/8") DIA. BEARING SEAT
R. 1/2"
101.6
4"
95.3
3-3/4"
460.4
18-1/8"
304.8
12"
TOP VIEW
374.7
14-3/4"
R. 3/8"
GAS
FLOW
PIPE 254mm (10") I.D.
273.1mm(10-3/4") O.D.
447.7
17-5/8"
R. 3/8"
WATER
IN
177.8
7"
254
10
273.1
10-3/4"
198.8
6-1/4"
12 X 3/8" BOLTS ON 29 1/2" B.C.
22.2
7/8"
238.1
9-3/8"
31.8
1-1/4"
I AND
EXIT


SAME AS OPPOSITE END
TAR AND WATER EXIT (CAPPED)
8 x 9/16" HOLES ON 12" B.C.
298.1
11 1/2"
142.9
5 5/8
3.2
1/8
FIBER GASKET HERE
38.1
1 1/2"
BOTTOM VIEW
358.8
14 1/8"
R 3/8"
254 mm (10") I.D. 273.1 mm (10 3/4") O.D.
12 x 3/8" BOLTS ON 251/2" B.C.
473.1
18 5/8"
SIDE VIEW

MARK V°	RPM	CAPACITY CUFT PER HR 100% FULL	FEEDER SPEED	AIRLOCK 80% FULL
1-41201-E	11-RPM	242	253	150



AIRLOCK ASSEMBLY
MK-1-41201-

NOTE -
- DIMENSIONS AND NOTES PERTAINING TO THE GEARED MOTOR ARE FOR THE TYPE GENERALLY FURNISHED AND ARE SUBJECT TO SLIGHT VARIATION IF OTHER TYPE IS USED

DIMENSIONS FOR FLANGE OF VALVE ARE SAME AS FOR FLANGE EXCEPT FOR THREE (3) AS SHOWN

			FLOATING SEAL AIRLOCK OUTBOARD BEARING DRIVE ASSEMBLY	JOY MANUFACTURING CO (CANADA) LTD PRECIPITATION DIVISION KITCHENER ONT — MONTREAL QUE

APPENDIX B

Experimental Data

Table B1. PRELIMINARY RUN DATA

1981 Date of Run	June 09	June 15	June 16
Gasifier Operating Data			
Operation Duration*, h	0.58[1]	3.42	6.25
Feed Total (Dry), kg	240.8	481.5	682.2
Feed Moisture, percent	--	--	38
Air Flowrate (Average), kg/h	207.7	281.4	332.4
Combustion Zone Temperature Range, K	1028-1408	939-1473+	398-873
Apparent Air to Fuel Ratio	0.50	2.00	3.05
Gas Data (Dry Basis)			
Heating Value, MJ/m^3	--	5.14	3.58
Exit Temperature (Average), K	364	415	673
Analysis, mole percent			
CO_2	--	8.2	11.5
H_2	--	7.2	12.9
N_2	--	55.4	57.0
CH_4	--	3.8	1.7
CO	--	21.4	9.9
Ar & other	--	4.0	7.1

[1] Forced shutdown due to excessive smoke leakage.

* Actual operating time during which combustible gas being produced. Does not include warm-up period.

Table B2. FORMAL RUN DATA

1981 Date of Run	June 23	June 29	June 30
Gasifier Operating Data			
Operation Duration*, h	2.75[1]	2.08[2]	12.08[3]
Feed Total (Dry), kg	361.2	301.0	1507.2
Feed Moisture, percent	33.5	30.3	37.3
Air Flowrate (Average), kg/h	150.1	295.1	252.4
Combustion Zone Temperature Range, K	868-1473+	833-1303	413-1473+
Apparent Air to Fuel Ratio	1.14	2.04	2.02
Gas Data (Dry Basis)			
Heating Value, MJ/m^3	--	--	5.38
Exit Temperature (Average), K	358	355	543
Analysis, mole percent			
CO_2	--	--	9.3
H_2	--	--	10.8
N_2	--	--	53.2
CH_4	--	--	3.2
CO	--	--	21.4
Ar & other	--	--	2.0

[1] Ash scraper stalled. Caught on grate, which had warped.

[2] New grate installed. Shutdown temporarily to replace wood supply with clean, sand-free chips.

[3] Maxon burner operated for 7 hours.

* Actual operating time during which combustible gas being produced. Does not include warm-up period.

Table B2 (Cont'd). FORMAL RUN DATA

1981 Date of Run	July 01	July 09	July 15
Gasifier Operating Data			
Operation Duration*, h	2.33[1]	2.50[2]	4.08[3]
Feed Total (Dry), kg	321.0	321.0	481.5
Feed Moisture, percent	35.6	29.6	51.1
Air Flowrate (Average), kg/h	211.3	247.8	168.5
Combustion Zone Temperature Range, K	973-1473+	423-1288	871-1330
Apparent Air to Fuel Ratio	1.53	1.93	1.43
Gas Data (Dry Basis)			
Heating Value, MJ/m^3	4.28	--	--
Exit Temperature (Average), K	673	523	360
Analysis, mole percent			
CO_2	9.7	--	--
H_2	9.1	--	--
N_2	58.8	--	--
CH_4	3.0	--	--
CO	15.1	--	--
Ar & other	4.3	--	--

[1] Centrifugal tar extractor motor burned out causing shutdown.

[2] Severe gas leakage.

[3] Tar extractor cut out, causing severe gas leakage.

* Actual operating time during which combustible gas being produced. Does not include warm-up period.

Table B2 (Cont'd.). FORMAL RUN DATA

1981 Date of Run	July 16	July 22	August 10
Gasifier Operating Data			
Operation Duration*, h	2.0[1,2]	3.92[3]	5.42[3,4]
Feed Total (Dry), kg	160.5	642.0	461.5
Feed Moisture, percent	50.8	37.4	23.8
Air Flowrate (Average), kg/h	141.8	290.2	235.9
Combustion Zone Temperature Range, K	823-1423	468-1473+	858-1473+
Apparent Air to Fuel Ratio	1.77	1.77	2.77
Gas Data (Dry Basis)			
Heating Value, MJ/m^3	--	--	6.04
Exit Temperature (Average), K	368	388	362
Analysis, mole percent			
CO_2	--	--	6.3
H_2	--	--	8.8
N_2	--	--	52.2
CH_4	--	--	4.0
CO	--	--	26.3
Ar & other	--	--	2.3

[1] Centrifugal tar extractor continued to cut out.

[2] Layer of clinker spread on grate to insulate it; did not work and grate was damaged.

[3] Severe gas leakage forced shutdown.

[4] Ran without grate.

* Actual operating time during which combustible gas being produced. Does not include warm-up period.

Table B2 (Cont'd.). FORMAL RUN DATA

1981 Date of Run	August 11	August 18	September 03
Gasifier Operating Data			
Operation Duration*, h	2.45[1]	0.75[2,3]	1.25[1,4]
Feed Total (Dry), kg	622.0	140.4	160.5
Feed Moisture, percent	29.0	41.2	--
Air Flowrate (Average), kg/h	211.3	176.5	248.1
Combustion Zone Temperature Range, K	1073-1473+	923-1403	
Apparent Air to Fuel Ratio	0.83	0.94	1.93
Gas Data (Dry Basis)			
Heating Value, MJ/m^3	5.08	--	--
Exit Temperature (Average), K	433	368	458
Analysis, mole percent			
CO_2	5.4	--	--
H_2	6.0	--	--
N_2	56.8	--	--
CH_4	3.4	--	--
CO	23.5	--	--
Ar & other	4.8	--	--

[1] Severe gas leakage forced shutdown.

[2] Centrifugal tar extractor bearings damaged.

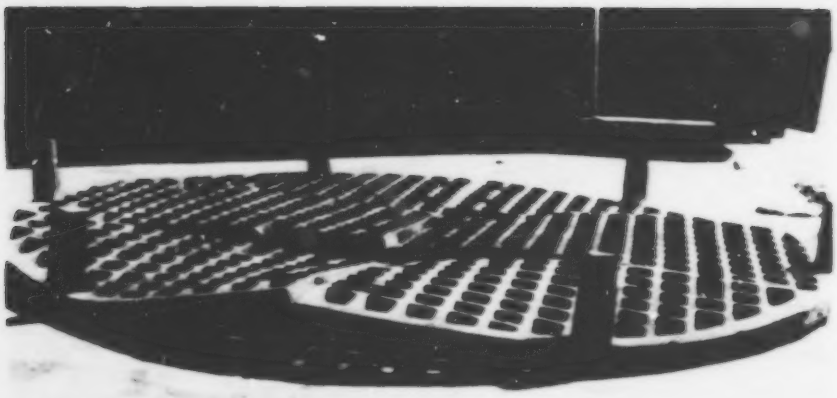
[3] Ran with ash scraper removed.

[4] Ran diesel engine on wood gas.

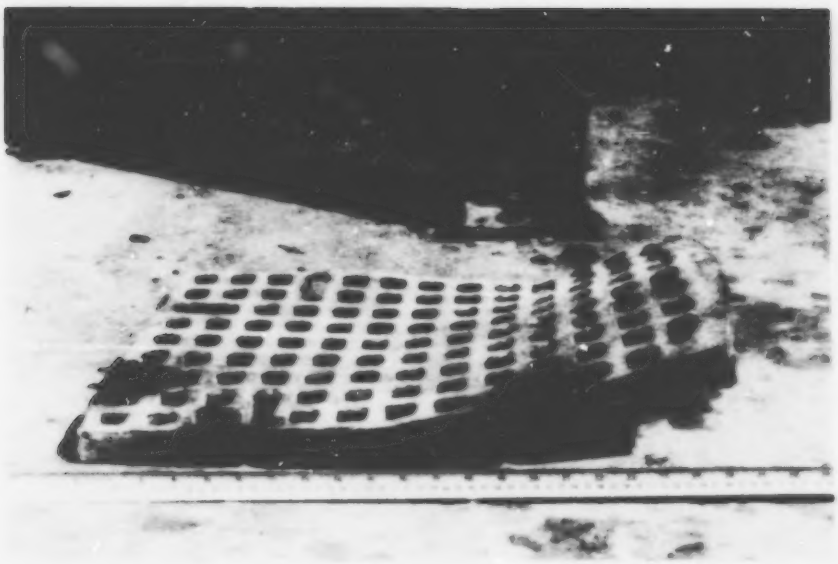
* Actual operating time during which combustible gas being produced. Does not include warm-up period.

APPENDIX C

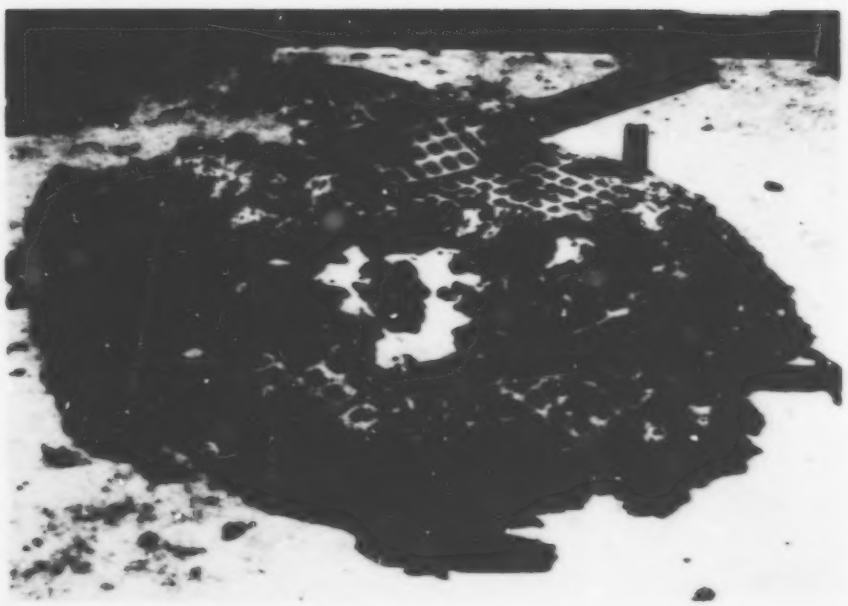
Failure Photographs



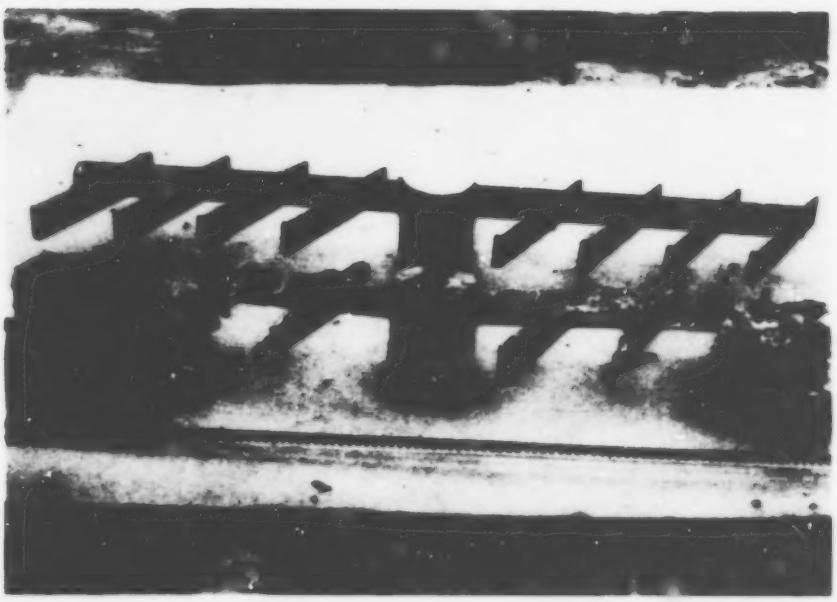
Photograph C1. REASSEMBLED GRATE SHOWING WARPAGE



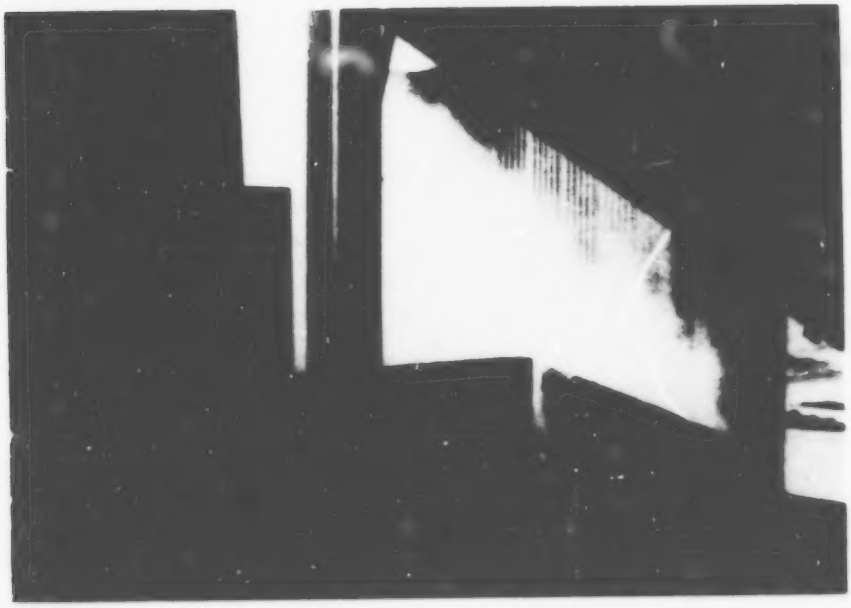
Photograph C2. GRATE SECTION SHOWING SEVERE WARPAGE



Photograph C3. REASSEMBLED GRATE SHOWING SEVERE DAMAGE DUE TO OVERHEATING



Photograph C4. COMPARISON OF NEW AND SEVERELY DAMAGED ASH SCRAPERS



Photograph C5. MILD SMOKE LEAKAGE FROM ROTARY AIRLOCK FEED SYSTEM

APPENDIX D

Economic Analysis

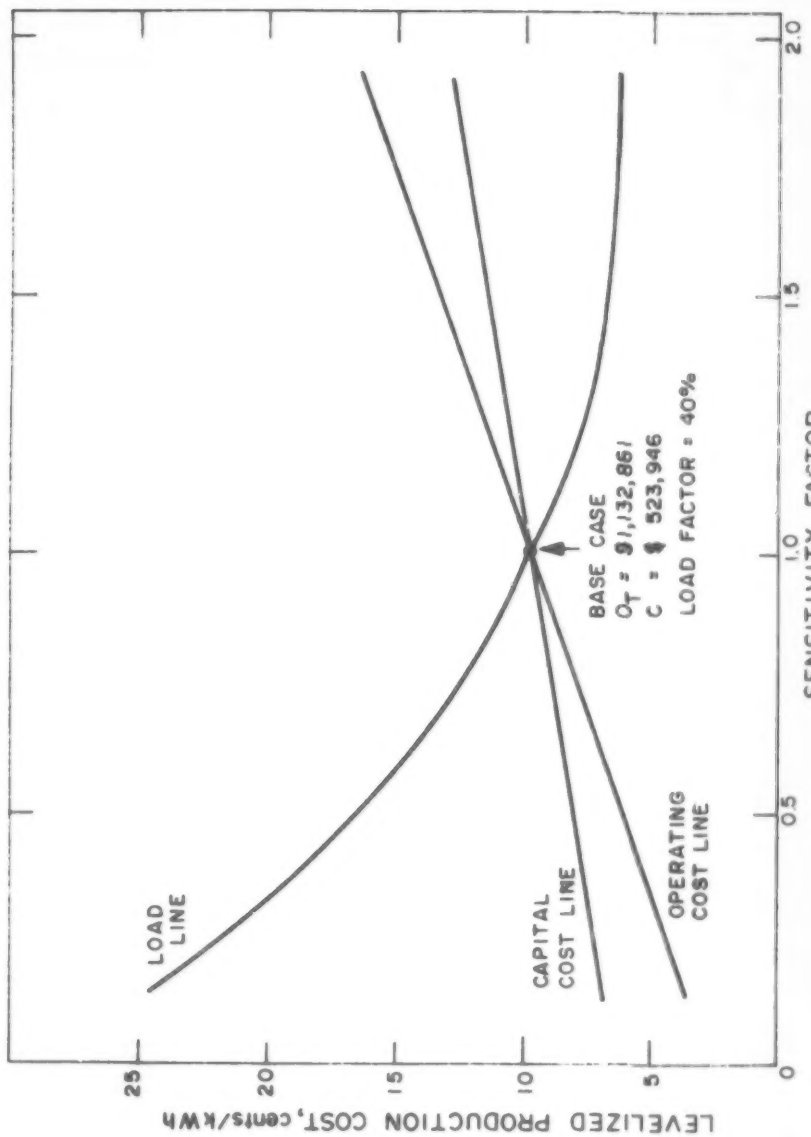


Figure DI. LEVELIZED ELECTRICITY COST FOR WOOD GASIFIER - MOTOR - GENERATOR (utilization of waste wood at no cost)

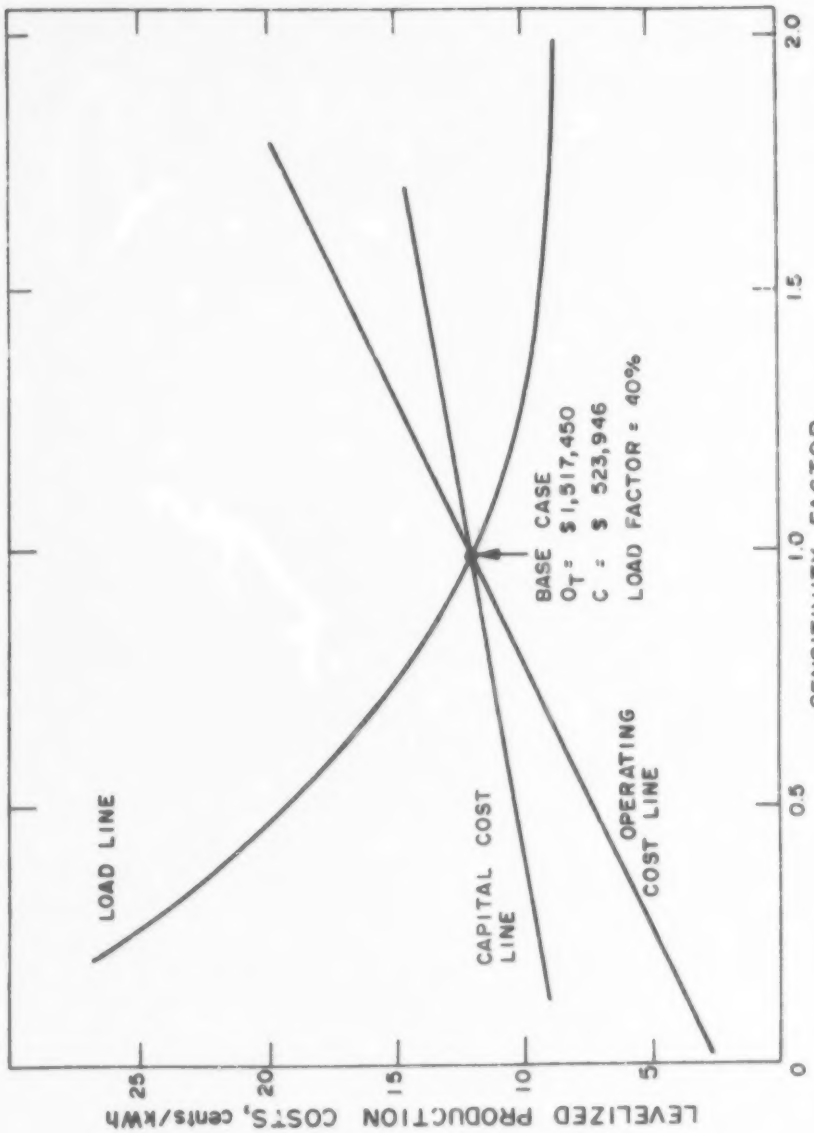


Figure D2. LEVELIZED ELECTRICITY COST FOR WOOD GASIFIER - MOTOR - GENERATOR (utilization of wood at $25/oven dried tonne)

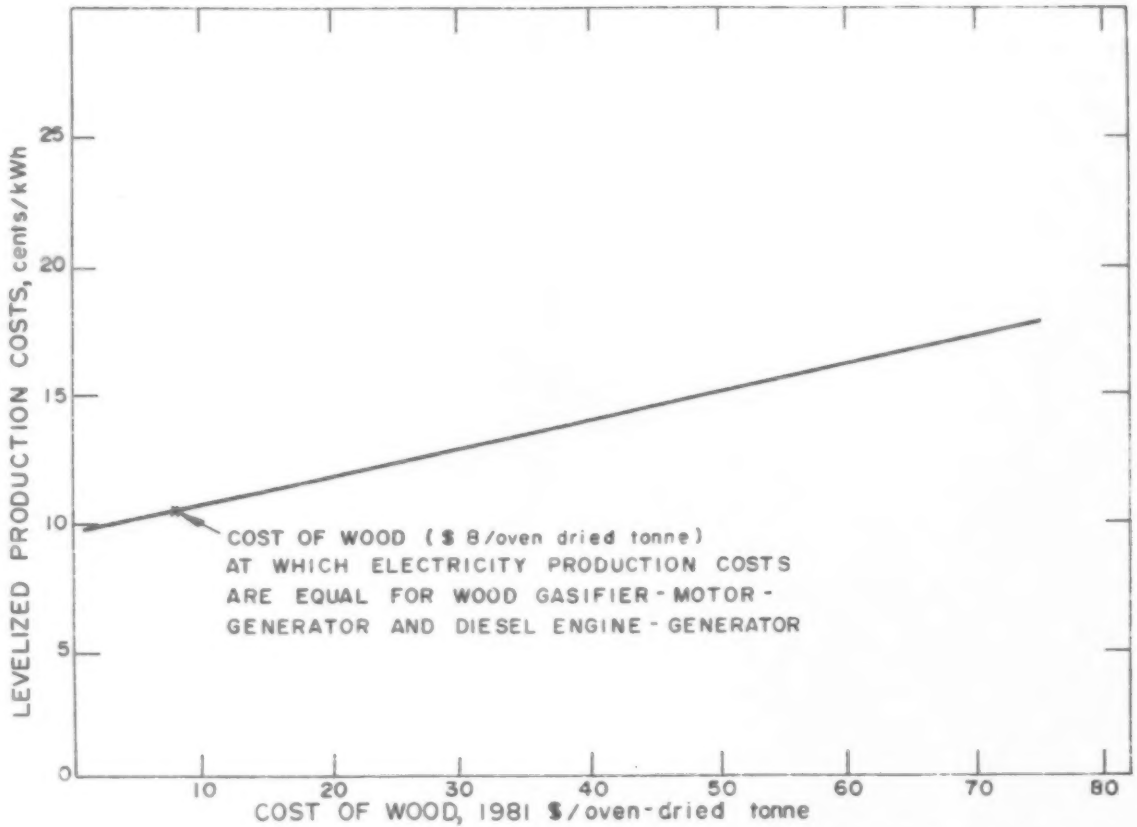


Figure D3. SENSITIVITY ANALYSIS OF WOOD COST VERSUS ELECTRICITY COST FOR WOOD GASIFIER-MOTOR-GENERATOR

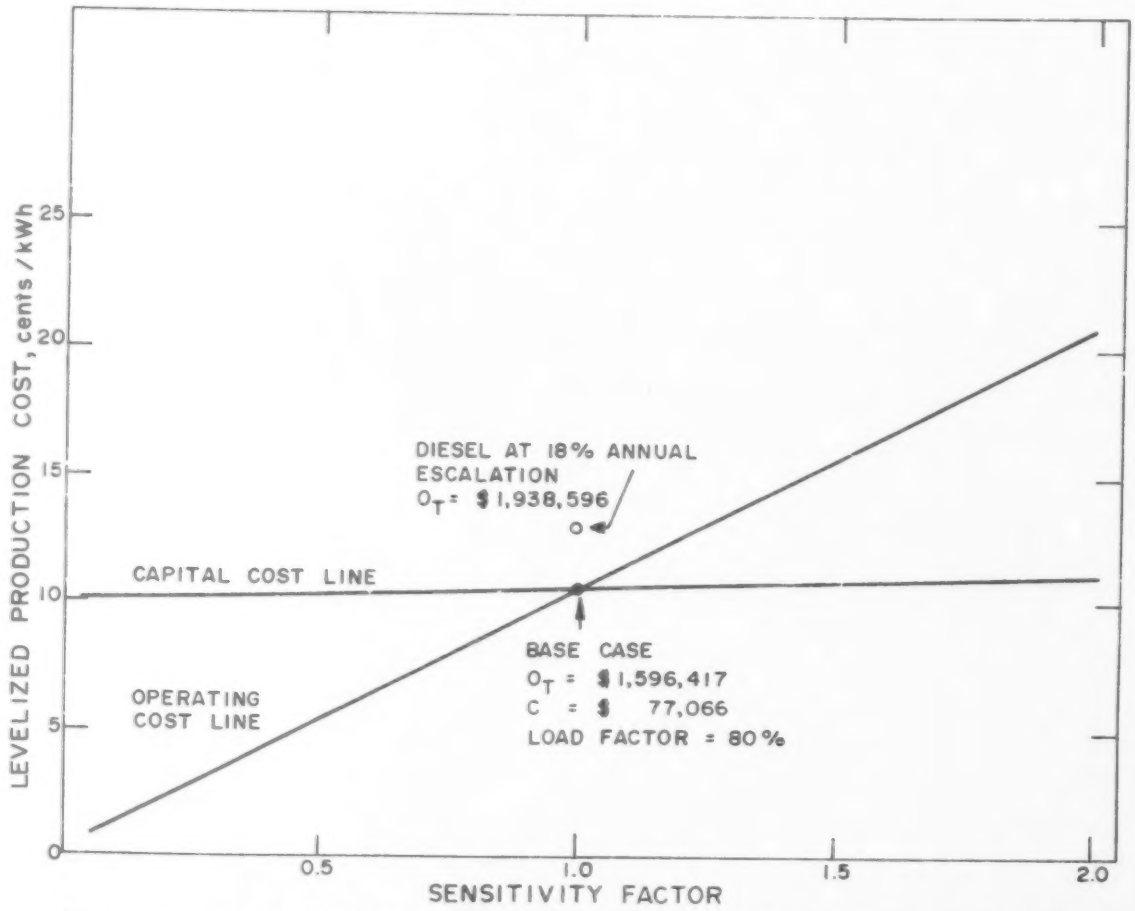


Figure D4. LEVELIZED ELECTRICITY COST FOR DIESEL ENGINE-GENERATOR

APPENDIX E

Project Work Statement

The following is the work statement for the project entitled "Hudson Bay Wood Gasification Plant (Phase IV)".

Task 1: Preparation of Plant

The gasification plant will be prepared for the extended runs. Modifications are required before the runs are done.

(a) With the present feed system there is a large smoke leakage through the feed screw and into the surroundings. The original rotary air lock did not seal properly and also deteriorated rapidly. Two alternatives are presently being evaluated to prevent smoke leakage. One is to install an intermediate hopper before the feed screw which would be equipped with two knife edge gate valves to provide an airtight seal. The second alternative is rotary air lock feeders which are being examined to determine suitability for feeding wood chips.

(b) The rabble arm which scrapes the ash to the ash removal screw requires replacement. The previous 316 S.S. rabble arms have deteriorated due to the extreme temperatures found in the gasifier. High temperatures have decreased strength and promoted corrosion and or erosion of the rabble arm. Two new rabble arms will be constructed of the best available material to survive the conditions found in the gasifier bed. Also the rabble arm will be continuously rotated in the reverse direction when not removing ash to distribute the wood feed and eliminate localized hot spots. An alternative approach is to install a grate which will allow an

unobstructed movement of ash. The grate will be fabricated from a special H.F. Meehanite iron cast.

(c) It has been concluded that the wood feed moisture content must be in the 20 to 30 percent range. Wood chips available at Hudson Bay are generally in excess of 50 percent moisture. Commercial dryers which would dry the wood on a continuous basis as the gasifier demanded have long delivery times. The remaining alternative is to dry the wood chips with a locally constructed drying system. Rather than operating as a function of gasifier demand the drying process would begin immediately after the equipment was assembled with the dry chips being stock piled. A covered storage area with a capacity of 750 m^3 (22,000 ft^3) is required to supply the gasifier for 15 days continuous operation.

(d) An insulated line from the cyclone to the Maxon industrial burner needs to be installed. This line will bypass the remainder of the cleaning train allowing the burner to be tested on the hot gas to conserve sensible heat.

(e) Before the extended run on the diesel engine there are modifications to the gas cleaning train required. The present system does clean and cool the gas but water consumption is high. Besides the availability of this volume there are the related disposal problems. Changes to the drier column and water sprayer will be made based on the findings of the Wood Gas Cleaning Study conducted by Saskatchewan Power Corporation.

(f) Additional thermocouples need to be installed to provide more information on gasifier bed characteristics.

(g) The flare hood requires reinforcing to support the taller stack which was installed last year.

Task 2: Preliminary Extended Runs

Two to three runs will be conducted to test out the revisions made to the gasifier system. These runs will be done in conjunction with Task 1.

Task 3: Extended Runs on Gasification Plant and on Diesel Engine

Extended runs will be attempted with a specified fuel over a test period of 60 consecutive days. During this 60 day test period, SPC will attempt to run the gasifier continuously for a period of at least 15 consecutive calendar days.

During this extended test run of 15 consecutive calendar days, SPC will operate a 150 KW diesel engine for at least 7 calendar days on the wood gas that is produced. The diesel engine will be operated on the wood gas for a period of at least 7 hours in each of these 7 calendar days. During the remaining 17 hours of each of these 7 calendar days, the wood gas that is produced can either be flared or burned in the industrial burner if SPC does not wish to operate the diesel engine.

During the other 8 days of the 15 day extended test run period, SPC can use the wood gas that is produced either to power the 150 KW diesel engine or to fuel the industrial burner. The diesel engine or the industrial burner will be operated on the wood gas for a period of at least 7 hours in each of these 8 calendar days. During the remaining 17 hours of each of these 8 calendar days, the wood gas that is produced can be flared if SPC does not

wish to operate the diesel engine or the industrial burner.

Even if the 60 day test period has not entirely passed, SPC will have completed this task if all of the following conditions have been met:

1. the gasifier has been operated for a period of 15 consecutive calendar days

AND

2. the wood gas that was produced has been used to operate the 150 KW diesel engine for a total of at least 49 hours at the rate of 7 hours in each of 7 calendar days throughout the 15 day extended test run period

AND

3. the wood gas that was produced has been used to operate either the 150 KW diesel engine or the industrial burner for a combined total of at least 105 hours at the rate of 7 hours in each calendar day throughout the 15 day extended test run period.

Even if an extended run of 15 consecutive calendar days has not been achieved, SPC will have completed this task at the end of the 60 consecutive calendar day test period.

When the diesel engine is operating on wood gas, SPC will analyze the wood feed and the gas produced on a continuous basis. The electricity produced by the diesel/electric generator will also be measured on a continuous basis.

When the wood gas is being combusted in the industrial burner, the wood feed and the gas produced will be analyzed on a continuous basis.

Task 4: Gasifier Plant Emissions

While the extended runs on the gasification plant and on the diesel engine are being conducted, the quantity and quality of liquid emissions from the gas cleaning system will be determined, together with the characteristics of the ash and oil samples obtained from the diesel engine.

Task 5: Data Evaluation

Under this task data obtained under Tasks 3 and 4 will be analyzed and recommendations made for improvement of the system whenever a new plant may be built.

Task 6: Report Writing

A report will be prepared based on good engineering principles. Economics will also be given both for a similar sized plant producing fuel gas as well as electrical power.

Task 7: Technology Transfer

The Project Manager/Engineer will present a paper entitled "Wood Gasification for Production of Electricity and Industrial Fuel Gases" to the Bioenergy Research and Development Seminar to be held in Ottawa on March 24-25, 1981.

SPC will provide a reasonable opportunity for interested parties to visit the project site to see the gasifier in operation. In addition, SPC will ensure that the pilot plant data will be available and will be provided on request to the public.